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Gulf Coast Salt Domes
Geologic Area Characterization Report
North Louisiana Study Area

COMPLETED

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Volume IV
Technical Report

July 1982

Law Engineering Testing Company
2749 Delk Road, S.E.
Marietta, GA 30067

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ABSTRACT

The Louisiana Geologic Area Characterization Report (ACR) is a compilation of data gathered during the Area Characterization phase of the Department of Energy's National Waste Terminal Storage program in salt.

The characterization of Gulf Coast Salt Domes as a potential site for storage of nuclear waste is an ongoing process. This report summarizes investigations covering an area of approximately 2,590 km^2 (1,000 mi^2). Subsequent phases of the program will focus on smaller land areas and fewer specific salt domes, with progressively more detailed investigations, possibly culminating with a license application to the Nuclear Regulatory Commission.

The data in this report are a result of drilling and sampling, geophysical and geologic field work, and intensive literature review. The ACR contains text discussing data usage, interpretations, results and conclusions based on available geologic and hydrologic data, and figures including diagrams showing data point locations, geologic and hydrologic maps, geologic cross sections and other geologic and hydrologic information. An appendix contains raw data gathered during this phase of the project and used in the preparation of these reports.

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GLOSSARY OF GEOLOGICAL TERMS

AGGRADATION - process of building up a surface by deposition.

ALLUVIUM - a general term for clay, silt, sand, gravel or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water; adj. alluvial.

ANGULAR UNCONFORMITY - an unconformity in which the younger overlying sediments rest upon the eroded surface of tilted or folded older rocks.

ANHEDRAL - a crystal in which the crystal faces are neither distinct nor characteristic of the particular mineral or element.

ANHYDRITE - a mineral consisting of anhydrous calcium sulfate: $CaSO_4$.

ANHYDROUS - a substance that is completely or essentially without water; an anhydrous mineral contains no water in chemical combination.

ANTICLINE - a fold, the core of which contains stratigraphically older rocks; it is convex upward; adj. anticlinal; ant. syncline.

AQUICLUDE - a body of relatively impermeable rock that is capable of absorbing water slowly but functions as an upper or lower boundary of an aquifer, and does not transmit water rapidly enough to supply a well or spring; "confining bed" is preferred.

AQUIFER - a body of rock that contains sufficiently saturated permeable material to yield significant quantities of water to wells and springs.

AQUIFUGE - an impermeable body of rock; "confining bed" is preferred.

AQUITARD - a body of impermeable material stratigraphically adjacent to one or more aquifers; "confining bed" is preferred.

AREAL MAP - a geologic map showing the horizontal extent and distribution of rock varieties or rock units exposed at the surface.

ARENACEOUS - sediment or sedimentary rock consisting entirely or partially of sand-size fragments, or having a sandy texture or the appearance of sand.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

ARGILLACEOUS - sediment or sedimentary rock consisting entirely or in part of clay-size particles or clay minerals.

ASPHALTIC ROCK - a porous rock that has been impregnated naturally with asphalt.

BENTONITE - a general term for the montmorillonitic clay minerals derived from volcanic ash.

BIOSPHERE - all the area occupied by or favorable for occupation by living organisms including parts of the lithosphere, hydrosphere, and atmosphere. For considerations related to salt dome hydrology, the scope of the biosphere is expanded to include man and his food chain, i.e., from drillable depths, ±9,144 meters (± 30,000 ft) deep in the earth's crust, to the base of the stratosphere.

BIOSTRATIGRAPHY - stratigraphy based on the paleontologic aspects of rocks or stratigraphy with paleontologic methods.

BITTERNS - a natural solution, in an evaporite basin, that resembles a saltworks liquor, especially in its high magnesium content.

BLOCK FAULTING - a type of normal faulting in which the crust is divided into structural or fault blocks of different elevations and orientations.

BLOWOUTS - gaseous outbursts that may occur within a salt mine at the time of blasting and are confined to anomalous zones.

BOUDINAGE - a structure in which an original, continuous, competent layer or bed between less competent layers has stretched, thinned, and broken at regular intervals into bodies resembling boudins (sausage links) elongated parallel to the fold axis.

BOUGUER ANOMALY - a gravity anomaly calculated by allowing for the attraction effect of topography but not for that of isostatic compensation.

BOUNDARY SHEAR ZONES - a zone that forms the boundary between a spine of salt and the outside of the salt dome, or between two spines.

BRECCIATED - said of a rock structure marked by an accumulation of angular fragments, or of an ore texture showing mineral fragments without notable rounding.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

BRINE WELL - a salt well from which water is taken to be evaporated for making salt.

CALCITE - a common rock-forming mineral: $CaCO_3$.

CALIPER LOG - a graphic record which shows, to scale, the diameter of a drilled hole.

CAPABLE FAULT - a fault on which movement at or near the ground surface has occurred at least once within the past 35,000 years, or has had movement of a recurring nature within the past 500,000 years; a fault which has been directly correlated with seismic events.

CAPROCK - a hard rock layer, usually anhydrite, calcite, and gypsum, commonly found overlying the salt stock.

CARBONATE - a sediment formed by the organic or inorganic precipitation from aqueous solution of carbonates of calcium, magnesium or iron.

CARBONIC ACID - A weak naturally occurring acid (H_2CO_3), formed from atmospheric water and carbon dioxide.

CATACLASIS - rock deformation accomplished by fracture and rotation of mineral grains or aggregates without chemical reconstitution.

CLASTIC - a rock or sediment composed principally of broken fragments that are derived from pre-existing rocks or minerals and have been transported individually.

COMMON DEPTH POINT - a point at depth at which seismic reflections are produced at different offset distances on several profiles.

COMPETENT - said of a bed or stratum that is able to withstand the pressures of folding without flowage or change in original thickness.

COMPRESSIVE STRENGTH - a material's resistance to the maximum compressive stress that can be applied to a material, under given conditions, before failure occurs.

CONDUCTANCE - a measurement of salinity or salt (electrolyte) concentration of a fluid.

CONDUCTIVITY - usually refers to electricity or ionic transfer as in an electrolyte; or thermal conductivity, transfer of heat.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

CONFINING BED - a zone or bed of impermeable or distinctly less permeable material adjacent to one or more aquifers; see aquitard.

CONFORMABLE - an unbroken sequence of strata in which the layers are formed one above the other in parallel order by regular uninterrupted deposition under the same general conditions.

CONTOUR MAPS - an illustration of the form and distribution of various types of data produced by joining points of equal value; e.g., structural, isopach, topographic.

COQUINA ROCK- a detrital limestone composed wholly or chiefly of mechanically sorted fossil debris; adj. coquinoid.

CORE - a cylindrical or columnar piece of solid rock or section of soil taken as a sample of an underground formation by a special hollow-type drill bit.

CREEP - slow deformation of solid rock resulting from a small, constant stress acting over a long period of time.

CUESTA - a hill or ridge with a gentle slope (dip slope) on one side and a steep slope (scarp face) on the other.

DECLIVITY - a descending slope.

DEGRADATION - the general lowering of the surface of the land by erosive processes.

DELTA - an alluvial deposit, usually triangular, at the mouth of a river.

DENDRITIC DRAINAGE PATTERN - drainage pattern characterized by irregular branching.

DENUDATION - the process of exposing strata by erosion of overlying materials.

DEPOCENTER - an area or site of maximum deposition.

DESOMANTICLINE - a series of structural highs and lows aligned along a linear axis, resembling a chain or string of beads.

DETRITUS - a collective term for loose rock and mineral material that is worn from an older rock by mechanical means and moved from its place of origin.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

DIAGENESIS - The process by which all the chemical, physical, and biologic changes, modifications or transformations are undergone by a sediment after its initial deposition, and during and after its lithification, exclusive of surficial alteration and metamorphism.

DIAPIR - a dome or anticlinal fold, the overlying rocks of which have been ruptured or pierced by the squeezing out of the plastic core material, such as salt or an incompetant shale.

DIAPIRISM - the process of piercing or rupturing of domes or uplifting overlying rocks by core material, such as salt.

DIP - the angle that a bedding or structural surface makes with the horizontal plane, measured perpendicular to the strike.

DISCONFORMITY - an unconformity in which the older rocks remained essentially horizontal during erosion or cessation of deposition during simple vertical rising and sinking of the crust.

DISSOLUTION - a space or cavity in or between rocks formed by the solution of part of the rock material.

DOME - see salt dome.

DOWNCUTTING - stream erosion in which the cutting is directed in a downward direction.

DOWNDIP - a direction that is downwards and parallel to the dip of a structural surface.

DOWN-HOLE GEOPHYSICAL LOGGING - the process of lowering an instrument into a borehole or well and recording continuously on a meter at the surface some physical property of the rock material being logged.

DRAG FOLDS - minor folds that form in an incompetent bed when the competent beds on either side of it move in such a way as to subject it to a couple; any fold that is a subsidiary part of a larger fold.

EARTHQUAKE INTENSITY/ACCELERATION - a measure of the effects of an earthquake at a particular place on humans and/or structures.

ENTRENCHMENT - the process of a stream eroding downward so as to form a trench.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

EPICENTER - the point on the Earth's surface which is directly above the focus of an earthquake.

EPICENTRAL INTENSITY - a measure of an earthquake's intensity at its epicenter.

EQUIDIMENSIONAL - a textural term describing a material in which all crystals or grains are essentially the same size.

ESCARPMENT - a long, more or less continuous cliff or relatively steep slope facing in one general direction, breaking the general continuity of the land by separating two level or gently sloping surfaces.

EUHEDRAL - a crystal in which the crystal faces are very distinct and characteristic of the particular mineral or element.

EUSTATIC - pertaining to worldwide changes of sea level that affect all of the oceans.

EVAPORITE - a nonclastic sedimentary rock composed primarily of minerals precipitated from a saline solution.

EXFOLIATION - the process by which thin concentric shells are successively broken loose from the bare outer surface of a large rock mass.

EXTERNAL SHEATH ZONE - a zone that forms the boundary between a spine of salt and the outside of the salt dome type of boundary shear zone.

EXTRUSION - the igneous process of emitting lava onto the Earth's surface; also, the rock so formed.

FACIES - the sum of all primary lithologic and paleontologic characteristics exhibited by a sedimentary rock and from which its origin and environment of formation may be inferred; the general aspect, nature or appearance of a sedimentary rock produced under or affected by similar conditions.

FAULT - a surface or zone of rock fracture along which there has been displacement.

FERRUGINOUS - pertaining to or containing iron.

FIRST ORDER LEVELING - spirit leveling to establish a horizontal line of sight of high precision and accuracy.

FISSILE - capable of being easily split along closely spaced planes.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

FLAGGY ROCK - rock that tends to split into layers 1 to 5 cm (0.39 to 1.96 in) in thickness.

FLEXURE - a fold formed by warping or other gentle deformation rather than by compression; c.f. hinge fault.

FLEXURE FAULT - a fault that originally occurred as a flexure.

FLUVIATILE - pertaining to river flow and river action.

FORMATION - a basic convenient unit of rocks, of considerable thickness and extent, used in mapping, describing, or interpreting the geology of a region, and the only formal classification that is used for completely dividing the whole geologic column all over the world into named units on the basis of lithology.

FORMATION PACKER - a drill-stem testing apparatus utilized in boreholes to isolate a particular zone of interest in the rock section by inflating flexible steel-meshed rubber cushions against the sides of the hole, thus permitting formation fluids to be sampled.

FRACTURE - general term for any break or separation in a rock.

FRIABILITY - the ease with which a material can be crumbled.

GEOHYDROLOGY - a term referring to the flow characteristics of subsurface waters; c.f. ground-water hydrology.

GEOID - the "figure of the Earth" considered as a sea level surface extended continuously through the continents.

GEOLOGIC OR STRATIGRAPHIC CROSS SECTIONS - a diagram that shows geologic features transected by a given plane (usually a vertical plane).

GEOLOGIC STRUCTURE - the general disposition, attitude, arrangement, or relative positions of the rock masses of a region or area; the sum total of the structural features of an area; also used to designate any physical arrangement of rocks, such as an anticline or fault, due to earth forces.

GEOMORPHOLOGY - the science that treats the general configuration of the Earth's surface and its relationship to geologic forces. The interpretative study of landforms; see physiography.

GEOPHYSICAL LOGS - a log obtained by lowering an instrument into a borehole or well, while recording continuously on a meter at the surface some physical property of the rocks through which it passes.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

GEOPRESSURED - subsurface condition in which the fluid pressures exceed the normal hydrostatic pressures, due generally to the weight of the overburden.

GEOSYNCLINE - a mobile downwarping of the crust of the Earth, measured in scores of kilometers, which is subsiding as sedimentary and volcanic rocks accumulate to a thickness of thousands of meters; adj. geosynclinal.

GLACIO-ISOSTASY - the state of hydrostatic equilibrium in the Earth's crust as influenced by the weight of glacial ice.

GLAUCONITE - a dull green, amorphous, and earthy or granular mineral of the mica group.

GOUGE - a thin layer of soft rock material between a salt plug and adjacent strata created by cataclasis during diapirism.

GRABEN - an elongated, relatively depressed crustal unit or block that is bounded by faults along its sides; down-dropped fault block; c.f. horst.

GRAIN DENSITY - specific gravity of the grains composing a sediment or sedimentary rock.

GROUND WATER - that part of the subsurface water which is in the zone of saturation.

GROUP - a major rock-stratigraphic unit, next higher in rank than formation; consisting wholly of two or more contiguous or associated formations having significant lithologic features in common.

GROWTH FAULT - a fault in sedimentary rocks that forms contemporaneously and continuously with deposition.

GYPSUM - a mineral consisting of hydrous calcium sulfate: $CaSO_4 . 2H_2O$.

HALITE - native salt; the mineral sodium chloride: $NaCl$.

HALOKINETICS - a general term for the study of the structure and mechanism of salt movements.

HALO-TECTONIC - pertaining to the forces resulting in salt movement.

HECTARE - a metric unit of land area equal to 10,000 square meters or 2.471 acres.

HEMATITE - a common iron mineral consisting of ferrous oxide: Fe_2O_3.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

HIATUS - a break or interruption in the continuity of the geologic record.

HINTERLAND - an area bordering, or within, an orogenic belt on the internal side, away from the direction of overfolding and thrusting.

HOMOCLINAL SHEAR ZONES - a tabular zone of rock that has been brecciated by parallel fracture along rock units which have the same dip.

HOMOGENEOUS SEISMICITY - seismic activity equally dispersed throughout its occurrence.

HORST - an elongated, relatively uplifted crustal unit or block that is bounded by faults on its long sides; uplifted fault block.

HOST ROCK - a body of rock which includes relatively small amounts of other rocks or mineral deposits.

HYDROGEOLOGY - the science that deals with subsurface waters and related geologic aspects of surface waters.

HYDROLOGY - the science that deals with continental water, its properties, circulation, and distribution on and under the Earth's surface and in the atmosphere.

IGNEOUS - said of a rock or mineral that solidified from a molten or partially molten state, i.e. from a magma; contrasted to sedimentary.

INDURATED - condition of a compact rock or soil hardened by the action of pressure, cementation, or especially heat.

INLIER - an area or exposed group of rocks surrounded by outcrops of younger rocks.

INTENSITY RECURRENCE FUNCTION - a statistically determined relationship expressing the probabilistic likelihood of experiencing a certain [earthquake] intensity as a function of time.

INTERFLUVES - the areas between rivers; esp. the relatively undissected upland or ridge between two adjacent valleys containing streams flowing in the same general direction and belonging to the same general drainage basin or watershed.

INTERGLACIAL - pertaining to the time interval between two successive glacial epochs, or between two glacial stages.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

INTERNAL BOUNDARY ZONE - a zone which forms the boundary between two salt spines.

INUNDATED - to be covered with water; flooded.

ISOCHORE - a line drawn through equal interval between two beds or other places.

ISOCHORE MAP - a map that shows the varying interval between two designated stratigraphic planes or horizons, possibly including one or more unconformities. c.f. isopach map.

ISOCLINAL FOLDS - a fold in which the limbs have been so compressed that they have the same dip.

ISOPACH - a line drawn on a map through points of equal thickness of a designated stratigraphic unit.

ISOPACH MAP - a map that shows the thickness of a designated stratigraphic unit; c.f. isochore map.

ISOSEISMAL - a line connecting points on the Earth's surface at which earthquake intensity is the same.

ISOSTASY - the condition of equilibrium [comparable to floating] of the units of the brittle crust above the denser plastic mantle. Principle of equilibrium level between coastal segments of equal area having same mass.

ISOSTATIC (SEA LEVEL CHANGES) - changes in sea level resulting from adjustments in the Earth's crust to maintain equilibrium among units of varying mass and density.

JUVENILE WATER - term applied to water that is known to be derived directly from magma and comes from the Earth's interior to the surface for the first time.

KAOLINITE - a common, white to grayish or yellowish clay mineral of the kaolin group: $Al_2 Si_2 O_5 (OH)_4$.

KNICKPOINT - a point of abrupt change in the longitudinal profile of stream valleys.

LENS - a geologic deposit bounded by converging surfaces, thick in the middle and thinning toward the edges.

LENTIL - a minor rock stratigraphic unit of limited geographic extent, being a subdivision of a formation and similar in rank to a member, and thinning out in all directions.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

LEVELING - the operation of determining the comparative altitude of different points on the Earth's surface.

LIGNITE - a brownish-black coal that is intermediate in coalification between peat and subbituminous coal.

LIMESTONE - a class of rock which is composed of at least 80 percent of calcium or magnesium carbonates.

LIMONITE - a general term for a group of brown, amorphous, naturally occurring hydrous ferric oxides not specifically identified.

LINEAMENT - an alignment of surficial features that is structurally controlled, such as stream beds, vegetation or soil or rock tone that are so controlled; commonly observed on aerial photos or topographic maps.

LINEAR - a straight or gently curved physiograhic feature on the Earth's surface.

LINEATION - a general term for any linear feature of whatever scale in a rock.

LITHOLOGY - the physical description of rocks on the basis of such characteristics as color, mineralogic composition, and grain size.

LITHOSPHERE - the solid portion of the earth, as compared with the atmosphere and hydrosphere.

LUTITE - sediment or sedimentary rock consisting principally of clay or clay-sized particles.

MARL - an old term loosely applied to a variety of materials, most of which occur as soft, loose, earthy, and semifriable or crumbling unconsolidated deposits consisting chiefly of an intimate mixture of clay and calcium carbonate in varying proportions, formed under either marine or fresh-water conditions.

MASSIFS - an embryonic salt dome rising from its source bed, still at depth.

MICRITE - a limestone with a very fine subcrystalline texture.

MODIFIED MERCALLI INTENSITY - scale (from I to XII) for evaluating earthquake shocks.

METAMORPHIC - any rock derived from preexisting rocks by mineralogical, chemical, and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, etc.

MHO - a unit of electical conductance equal to the reciprocal of ohm.

MICROFOSSIL - a fossil too small to be studied without the aid of a microscope.

MICROMHO - mho x 10^{-6}.

MICROCRYSTALLINE - said of the texture of a rock consisting of or having crystals that are small enough to be visible only under a microscope; also said of a rock having such a texture.

MICROSEISMIC MONITORING - earthquake measurement or observation by instrumental means of shocks below the sensitivity threshold of the conventional seismograph.

MINERALOGY - the study of minerals, their formation and occurrence, their properties and composition, and their classification.

NEOGENE - an informal usage for the period of time incorporating the Miocene and Pliocene of the Tertiary Period.

NERITIC - pertaining to the ocean environment or depth zone between low-tide level and 100 fathoms, or between low-tide level and approximately the edge of the continental shelf.

NONCONFORMITY - an unconformable contact between sedimentary rocks lying upon an eroded surface of older igneous or metamorphic rocks.

NORMAL FAULT - a fault in which the hanging (upper) wall appears to have moved downward relative to the footwall. The angle of the fault is usually 45-90°.

OFFLAP - the reverse of transgressive onlap, occurring where a shoreline has retreated seaward and progressively younger strata have been deposited in layers offset seaward; a type of overlap.

ONLAP - extension of successive stratigraphic units beyond the marginal limits of their predecessors onto older rocks as in the deposits of a trangressing sea; a type of overlap.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

OOLITHS - one of the small, round accretionary bodies in a sedimentary rock, usually calcium carbonate.

OOLITE - a sedimentary rock usually a limestone, made up chiefly of ooliths cemented to others.

OOLITIC LIMESTONE - an even textured limestone composed almost entirely of relatively uniform calcareous ooliths.

OROGENIC BELT - a linear region that has been subjected to folding and deformation during an orogenic cycle.

OROGENY - the process by which rock structures in mountainous areas were formed.

OUTLIER - an area or group of rocks surrounded by outcrops of older rocks.

OVERBURDEN - the loose soil, silt, sand, gravel or other unconsolidated material overlying bedrock.

OVERCONSOLIDATION - consolidation resulting from desiccation or from pressure of overburden that has since been removed by erosion.

OXBOW LAKE - the crescent-shaped body of standing water situated by the side of a stream in the abandoned channel (oxbow) after the stream formed a neck cutoff and the ends of the original bend were silted up.

PALEOGENE - an informal usage for the interval of geologic time incorporating the Paleocene, Eocene, and Oligocene of the Tertiary Period.

PALEOGEOGRAPHIC MAP - a map that shows the reconstructed physical geography at a particular time in the geologic past.

PALEONTOLOGY - the study of life in past geologic periods, based on fossil plants and animals and including phylogeny, their relationships to existing plants and animals, and the chronology of the Earth's history.

PELLET - a small, usually rounded, aggregate of accretionary material; also fecal matter from fossil organisms.

PELLETAL LIMESTONE - a limestone characterized by abundant pellets.

PENCIL - long, slender pieces of rock (anhydrite) resembling pencils.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

PENEPLAIN - a low, nearly featureless and gently undulating or almost-plane land surface of considerable area.

PERMEABILITY - the property or capacity of porous rock, sediment, or soil for transmitting a fluid without impairment of the structure of the medium.

PETROFABRIC - the textural features of a rock.

PETROLOGY - that branch of geology dealing with the origin, occurrence, structure and history of rocks, especially igneous and metamorphic rocks.

PETROGRAPHY - the branch of geology dealing with the description and classification of rocks, especially igneous and metamorphic rocks.

PHYSIOGRAPHY - the descriptive study of landforms; see geomorphology.

PIERCEMENT DOME - see diapir.

PIERCEMENT STAGE - a stage of salt dome development in which the salt rises vertically, penetrating the overlying strata.

PIEZOMETRIC SURFACE - see potentiometric surface.

PILLOWING - a stage of salt dome development in which the salt is said to move laterally into mounds or "pillows."

PINCH-OUT - the termination or end of a stratum, vein, or other body or rock by tapering or progressively narrowing to extinction.

PLASTICITY - the property of a material that enables it to undergo permanent deformation without appreciable volume change or elastic rebound, and without rupture.

POTASH - potassium carbonate, K_2CO_3.

POROSITY - the property of a rock, soil, or other material containing interstices, and the ratio of the volume of its interstices to its total volume.

POTENTIOMETRIC SURFACE - an imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well; c.f. piezometric surface.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

PRODELTA - that part of the delta that is below the effective depth of wave erosion, lying beyond one delta front and sloping gently down to the floor of one basin into which the delta is advancing.

PROLATE - designating the shape of a solid, especially of a spheroid having its polar axis longer than its equatorial diameter; cigar-shaped.

QUAQUAVERSAL DIP - dipping outward in all directions from a central point, as a dome in stratified rocks.

RADIONUCLIDE - a radioactive species of atom characterized by the number of neutrons and protons in its nucleus; a product of radioactivity.

REDBEDS - sedimentary strata composed largely of clastic materials that are predominantly red in color due to the presence of hematite.

RELICT - a relief feature or rock remaining after other parts have disappeard.

REMOTE SENSING - in a restricted sense the practice of data collection in the wavelengths from ultraviolet to radio regions; a practical outgrowth of airborne photography.

RESIDUAL GRAVITY - the difference between theoretical, calculated, and observed terrestrial gravity, measured in milligals.

RESISTIVITY - the resistance to electrical current of a rock unit, measured instrumentally as a reconnaissance method of determining the nature of rocks in the shallow subsurface.

RIFT - a narrow cleft, fissure, or other opening in rock made by cracking or splitting; a large strike-slip fault parallel to regional structures.

RIFT BASIN - a deep central cleft in the crest of a mid-oceanic ridge.

RIFT VALLEY - valley produced by subsidence of a block bounded by two rifts.

RIM SYNCLINES - downfolds that tend to develop around the periphery of salt domes due to sagging of the overlying strata into a circular void created by the removal of salt from the source strata.

SALINE - a natural deposit of common salt or of any other soluble salt, e.g., an evaporite; pertaining to, consisting of, or containing salt; refers also to various features related to a natural evaporitic environment, e.g., playa, salt lake, salt pan, etc.

SALT CORE - a cylindrical sample of salt obtained by drilling into a rock salt body with a hollow drill bit; also, the central portion of salt stock.

SALT DOME - a structure resulting from the upward movement of a salt mass.

SALT STOCK - the salt mass portion of a salt dome structure.

SANDSTONE - a cemented or otherwise compacted detrital sediment composed predominantly of quartz grains.

SEDIMENTARY ROCK - a rock resulting from the consolidation of loose sediment that has accumulated in layers.

SEISMIC - pertaining to an earthquake or Earth vibration, including those that are artificially produced.

SEISMICITY - the phenomenon of Earth movements.

SEISMIC REFLECTION - a geophysical technique which measures the time of energy from a seismic source which has been reflected.

SEISMIC SURVEY - the gathering of data from artificially induced vibrations.

SEISMOLOGY - the study of earthquakes; by extending the study of the structure of the interior of the Earth via both natural and artificially generated seismic signals.

SEISMOTECTONIC REGION - a region characterized by a relative consistency of historical seismicity and of structural activity among geologic features contained therein.

SERIES - a time-stratigraphic unit generally classed next in rank below a system, and above a stage, properly based on a clearly designated stratigraphic interval in a type area.

SHEAR - strain resulting from compressive stresses that cause or tend to cause contiguous parts of a body to slide relative to each other in a direction parallel to their plane of contact; usually at an angle other than perpendicular to the direction of stress.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

SHALE - a laminated sediment in which the constituent particles are predominantly of the clay grade.

SHEAR MODULUS/S-WAVE VELOCITY -rigidity or shear modulus is a measure of the stress-strain ratio for a simple shear.

SHEAR WAVES - that type of seismic body wave which is propagated by a shearing motion of material so that there is oscillation perpendicular to the direction of propagation.

SHEATH (Lighology)- rock material, commonly shale, which surrounds or encompasses a salt plug.

SHEATH (Struct.)- pertaining to the external zone of a salt stock in which expansion of the salt has taken place, increasing the porosity and permeability.

SIDERITE - a rhombohedral mineral: $FeCO_3$.

SIDETRACKING - the practice of diverting multiple subsurface drill-holes from a single surface drill-hole.

SINKHOLE - a general term for a depression in an area of karst topography that is formed either by the solution of the surficial limestone or by the collapse of underlying caves.

SLABBING/SPALLING (OF WALLS) - the natural process of sloughing of large slabs of salt from the walls of mine workings.

SLOPE STABILITY - the quality of permanence or resistance of a natural or artificial slope to failure by landsliding.

SOLUTION - a process of chemical weathering by which rock material passes into solution.

SONIC LOG - an acoustic log continuously recording travel time of sound from the surface to an instrument lowered down a borehole.

SPALLING - see slabbing/spalling.

SPINE - a vertical protrusion of a salt stock which may or may not move upward at a different rate than the rest of the stock.

STACKING - a statistical method of processing seismic records that has the effect of averaging the intensity of the rays of energy from a single reflection point, while reducing the relative amount of noise or signal interference.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

STALACTITE - a cylindrical or conical deposit of minerals hanging from the roof of a cavern.

STALAGMITE - a column or ridge of material rising from the floor of a cavern or mine, caused by water dripping down from above.

STRADDLE-PACKER - a drill-stem testing apparatus utilized in boreholes to isolate a zone or interval of interest in the rock section (see formation packer).

STRATIGRAPHY - the arrangement of strata especially as to geographic position and chronological order of sequence: the branch of geology that deals with the description of minor and major divisions of rock.

STRATUM - a tabular or sheet-like mass, or a single and distinct layer, of monogeneous or gradational sedimentary material, distinguishable from mass above and below.

STREAM REACH - arbitrary lengthwise section of a stream.

STRIKE - the direction or trend of a structural surface with the horizontal plane.

STRUCTURAL GEOLOGY - that branch of geology that deals with the form, arrangement, and internal structure of the rocks.

STRUCTURE - the general disposition, attitude, arrangement, or relative positions of the rock masses of a region or area.

SUBAERIALLY - occurring beneath the atmosphere or in the open air; esp. said of conditions and processes (such as erosion) that exist or operate on or immediately adjacent to the land surface; c.f. - subaqueous.

SUBHEDRAL - a crystal in which the crystal faces are intermediate between distinct and non-distinct.

SYLVITE - a white or colorless isometric mineral, potassium chloride (KCl). It is the principal ore of potassium.

SYNCLINE - a fold, the core of which contains the stratigraphically younger rocks; it is concave upward.

SYNTHETIC SEISMOGRAM - artificial seismogram produced by computer from the acoustic velocity log of a well.

TARRY OIL SEEP - a place of emergence of tar-like petroleum as a result of the slow migration from its buried source, through minute pores or fissures.

GLOSSARY OF GEOLOGICAL TERMS (Continued)

TECTONIC - dealing with the rock structure and external forms resulting from the deformation of the earth's crust; as applied to earthquakes it is used to describe shocks not due to volcanic action or the collapse of caverns or landslides.

TECTONIC STRUCTURE - a large scale dislocation in or distortion of the Earth's crust.

TERRACE - any long, narrow, relatively level, or coastward gently inclined surface bounded on one edge by a steeper descending slope and also along the other by a steeper ascending slope; a large bench or step-like ledge.

TERRIGENOUS - produced from or of the Earth, terrigenous deposits are sediments derived from the land and deposited in shallow marine area.

TERRESTRIAL - pertaining to the land surface of the earth; terrestrial deposits are those made on land, above tidal reach.

THROW - on a fault, the amount of vertical displacement.

TILT - the angle at the perspective center between the plumb line and the perpendicular from the interior perspective center to the plane of a photograph.

TILTMETER - an instrument that measures slight changes in tilt of the Earth's surface.

TUFF - a compacted pyroclastic deposit of volcanic ash and dust that may contain up to 50% sediments such as sand or clay.

TUFFACEOUS MATERIAL - sediment containing up to 50% tuff.

UNCONFORMABLE - strata or stratification exhibiting the relation of unconformity to the older underlying rocks.

UNCONFORMITY - a substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in stratigraphic succession.

UPDIP REGION - a direction which is upwards and parallel to the dip of a structure or surface.

UPLIFT - a structurally high area in the crust produced by positive movements that raise or upthrust the rocks.

VALES - a rift valley or tectonic valley; also land between two parallel cuestas.

VIRGIN ROCK - fresh rock that has not been weathered.

VOID RATIO - the ratio of the volume of void space to the volume of solid substance in any material consisting of voids and solid material.

VUG - a cavity, often with a mineral lining of different composition from that of the surrounding rock.

WATERSHED - the area contained within a drainage divide above a specified point on a stream.

WOLD - a range of hills produced from differential erosion from inclined sedimentary rocks; a cuesta.

XENOLITH - rock fragments contained in an igneous body of rock which are foreign to the host rock; inclusion.

CONVERSION FACTORS

The conversion factors used in this report are based on the following table. In most instances, the metric-to-standard measurement conversions represent rounded-off figures in this report.

To convert from	To	Multiply by
millimeter (mm)	inch (in)	0.03937
meter (m)	foot (ft)	3.281
kilometer (km)	mile (mi)	0.6214
meter^2 (m^2)	foot^2 (ft^2)	10.76
kilometer^2 (km^2)	mile^2 (mi^2)	0.3861
hectare (-)	acre (-)	2.471
kilogram (kg)	pound (lb)	2.205
tonne (-)	ton (-)	0.893
liter (l)	gallon (gal)	0.2642
kilometers^3 (km^3)	miles^3 (mi^3)	0.244
kilopascal (kPa)	atmosphere (atm)	0.009869
milligrams per liter (mg/l)	parts per million (ppm)	1.0
liter per second (l/sec)	gallon per minute (gal/min)	15.85

ABBREVIATIONS AND ACRONYMS

AEC	Atomic Energy Commission
BEG	Texas Bureau of Economic Geology
BMI	Battelle Memorial Institute
BNI	Bechtel National, Inc.
DOE	Department of Energy
ERTS	Earth Resources Technology Satellite
FEA	Federal Energy Administration
LANDSAT	Earth Resources Technology Satellite (formerly ERTS)
LETCo	Law Engineering Testing Company
LSU/IES	Louisiana State University/Institute for Environmental Studies
MGAI	Mellen Geological Associates, Inc.
MM	Modified Mercalli
MMI	Modified Mercalli Intensity
MSGS	Mississippi State Geological Survey
MSL	Mean Sea Level
NAS	National Academy of Science
NRC	Nuclear Regulatory Commission
NSAI	Netherland, Sewell and Associates, Incorporated
NWTS	National Waste Terminal Storge
ONWI	Office of Nuclear Waste Isolation of Battelle Memorial Institute
ORNL	Oak Ridge National Laboratories
OWI	Office of Waste Isolation/Union Carbide Corp.
SCS	Soil Conservation Service
TAB	Technical Advisory Board
TNRIS	Texas Natural Resource Information System
USGS	United State Geological Survey
USM	University of Southern Mississippi

9 GEOLOGIC CHARACTERIZATION OF THE NORTH LOUISIANA STUDY AREA

The geologic characterization of the North Louisiana Study Area involves the description of the physiography and geomorphology, stratigraphy, structure, seismicity, and mineral resources. These studies lead to a fundamental understanding of the geology of the study area which is the basis for evaluating the tectonic stability of the area and geologic stability of the selected salt domes.

9.1 DESCRIPTION OF THE NORTH LOUISIANA STUDY AREA

The North Louisiana Study Area, which covers approximately 2,590 km^2 (1,000 mi^2), includes most of Bienville Parish, the southern half of Webster Parish, and portions of Jackson, Winn, Claiborne, Natchitoches, Bossier, Red River, and Lincoln Parishes (Figure 9-1). The elliptical study area is approximately 80 km (50 mi) long and 43 km (27 mi) wide.

Maximum relief of about 91 meters (300 ft) occurs between the steep-sided, flat-bottomed alluvial valleys and the upland areas (Figure 9-2). A dissected cuesta is located just within the northeastern border of the study area; its gentle dip slope faces northeastward.

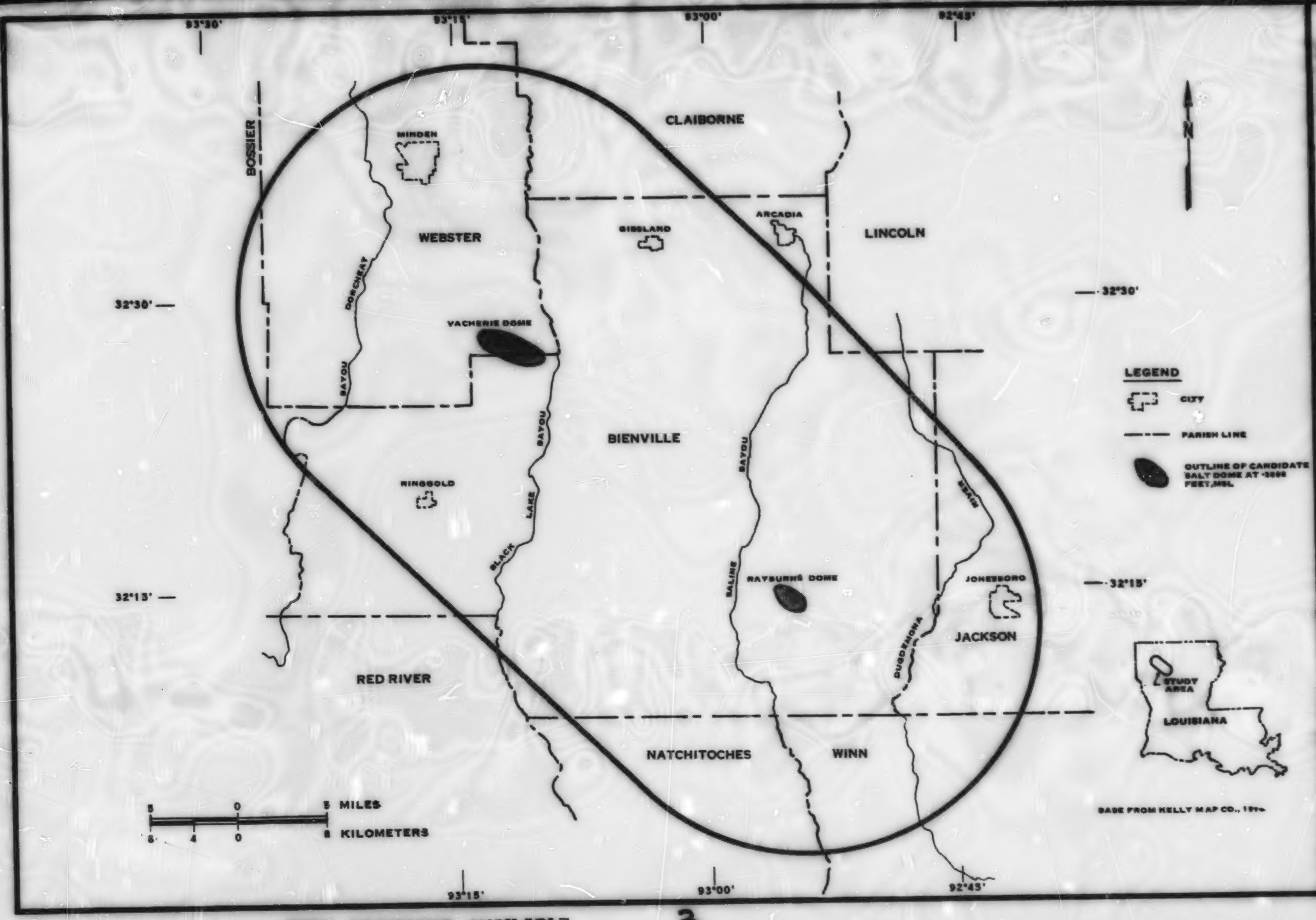
The high land in the northeast portion of the study area is a divide between the Red and Little River Basins and Ouachita River Basin. Bayou Dorcheat, Black Lake Bayou, and Saline Bayou flow southward into the Red River; the Dugdemona River flows southward and southeastward into the Little River; and Bayou D'Arbonne flows northward and eastward into the Ouachita River (Figure 9-2).

Although numerous small, artificial lakes, with surface areas of less than 16 hectares (40 acres) dot the landscape, only two large lakes with surface areas of several square miles occur within the study area: Lake Bistineau at the mouth of Bayou Dorcheat, and Kepler Creek Lake on a tributary of Black Lake Bayou. Both lakes were created by damming streams; however, a swamp had already existed in the area now covered by Lake Bistineau. Lake Bistineau State Park, a multipurpose recreational facility, is located on the northwestern shore of Lake Bistineau.

Land in the study area is used primarily for lumber production and cattle ranching. Some of the largest lumber producers in the state of Louisiana are located there. The principal trees are shortleaf and loblolly pines, cypress, ash, hickory, oak, and tupelo. Poultry is raised on a small scale.

The main population centers are Minden (population 5,000) and Jonesboro (population 5,000) (Figure 9-1). Numerous small incorporated and unincorporated communities with populations of less than 1,000 are scattered throughout the area. Shreveport (population 182,060), the closest major city, is located approximately 45 km (28 mi) west of Minden. The nearest commercial airport is in Shreveport.

Three railroads serve the study area (Figure 9-2). The North Louisiana and Gulf and the Louisiana and Arkansas Railroads run north-south in the eastern and western parts of the area,



NORTH LOUISIANA STUDY AREA

LOCATION MAP

JOB NO. MV 9500

FIGURE 9-1

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED _____ DATE 6/13/80
REVISED _____ DATE 12/17/80
REVISED _____ DATE 11 23 ?
APPROVED GHF DATE 12/23/80

T-1342-3

FIGURE 9-1

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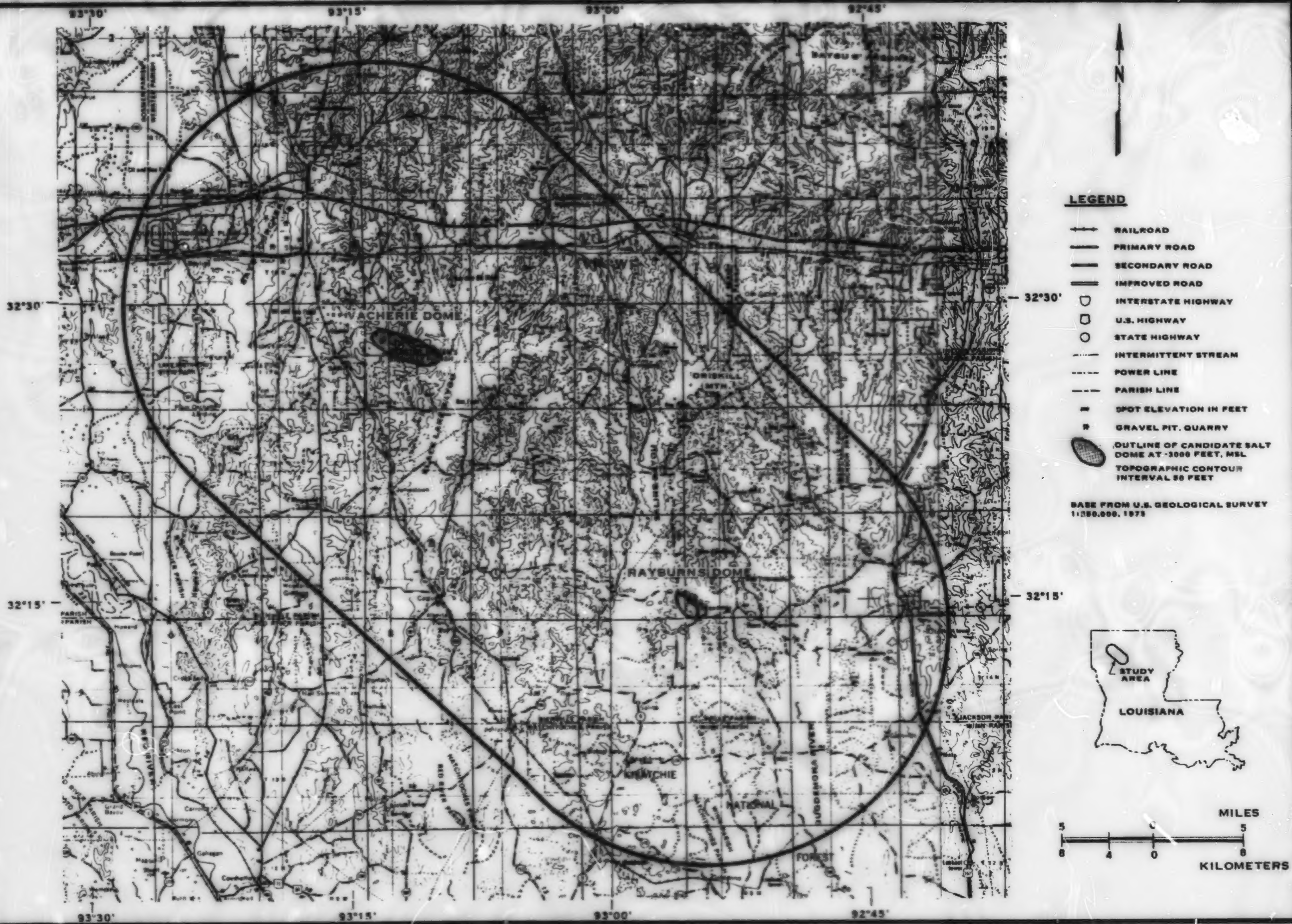

NORTH LOUISIANA STUDY AREA

TOPOGRAPHIC MAP

JOB NO. MV 9600

FIGURE 9-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED [illegible] DATE [illegible]
REVISED [illegible] DATE 12/13/80
REVISED [illegible] DATE [illegible]
APPROVED GHF DATE 12/23/80

T-1343-3

FIGURE 9-2

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respectively. The Illinois Central Gulf Railroad runs east-west, 10 km (6 mi) south of Minden.

One interstate highway and numerous hard-surfaced state highways cross the study area (Figure 9-2). A major, limited access, divided highway (Interstate 20) runs east-west, passing through Minden and Arcadia.

Significant mineral resources currently under development include oil, gas, sand, and gravel (see Section 9.3). Lignite deposits are not currently being exploited.

9.2 GEOLOGY OF THE NORTH LOUISIANA STUDY AREA

Both existing and newly developed data were compiled and used to characterize the physiography, geomorphology, stratigraphy, structure, seismicity, and mineral resources of the study area. Addressing these aspects of the geology enabled a fundamental understanding of the study area to evolve in relation to the regional framework, and provided a reliable basis for developing near-dome and over-dome geologic relationships.

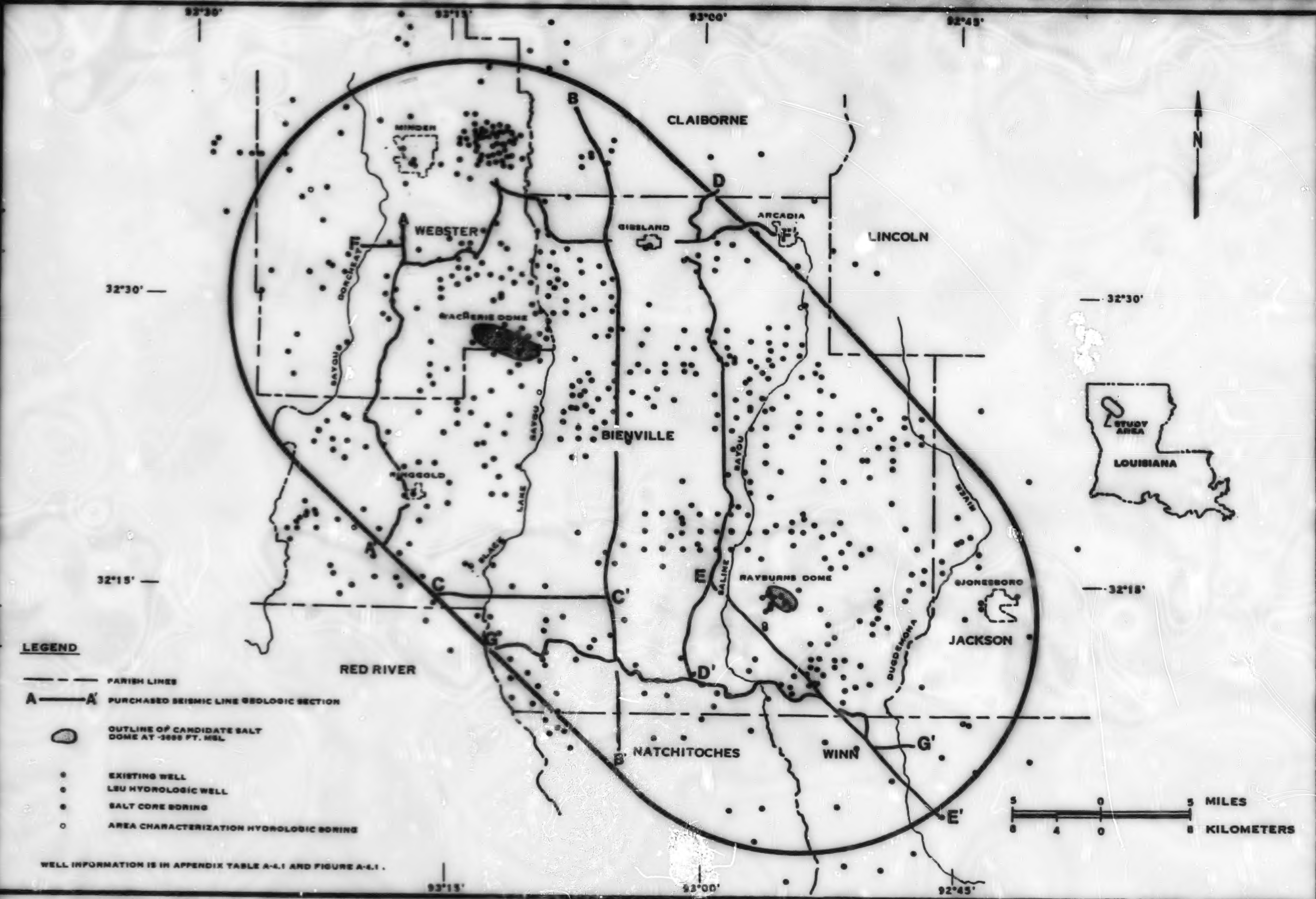
Locations of oil and gas wells from which well-log data were obtained and used in subsurface mapping and interpretation are shown in Figure 9-3, and in Table A-4.1 and Figure A-4.1 of the North Louisiana Appendix.

9.2.1 PHYSIOGRAPHY AND GEOMORPHOLOGY: The study area is located within the Ouachita-Red River Rolling Lands division of the Northern Gulf Coastal Plain Physiographic Province, between the Red River Lowland and the Ouachita Lowland (Figure 9-4). The

Gulf Coast Plain is underlain by Cretaceous, Tertiary, and Quaternary sediments that generally dip gently gulfward. Resistant outcrop belts conform generally to the coastline in a series of arcuate and parallel, low, asymmetrical ridges forming cuestas or wolds.

Within the more restricted limits of the study area, however, the near-surface structure and its physiographic expression are primarily related to the Sabine Uplift centered to the southwest, and to the nearby Red River on the west. As a result of mid-Tertiary structural activity, the early Tertiary formations on the flanks of the broad uplift dip gently away from its center. In the study area, northeast of the uplift, the beds dip northeastward and are exposed in belts forming cuestas which strike northwest-southeast (Figure 9-5). South of the Sabine Uplift the beds dip Gulfward and are expressed at the surface by northeast-southwest trending outcrop belts and the Kisatchie Wold (Figure 9-4).

The greatest relief within the study area, almost 91 meters (300 ft), occurs in northeastern Bienville Parish along a dissected cuesta formed by the resistant sands of the lower part of the Cockfield Formation and the ironstone ledges of the upper part of the Cook Mountain Formation overlying less resistant silts and clays of the Cook Mountain Formation. Driskill Mountain, the highest point in Louisiana, stands 163 meters (535 ft) above mean sea level (MSL) and forms a part of this cuesta (Figure 9-2). The cuesta forms the drainage divide between Bayou D'Arbonne (which flows to the east into the Ouachita River) and



LEGEND

— — — PARISH LINES

A———A' PURCHASED SEISMIC LINE GEOLOGIC SECTION

OUTLINE OF CANDIDATE SALT DOME AT -3000 FT. MSL

● EXISTING WELL

● LEU HYDROLOGIC WELL

● SALT CORE BORING

○ AREA CHARACTERIZATION HYDROLOGIC BORING

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1 .

NORTH LOUISIANA STUDY AREA
LOCATION OF WELLS
AND SEISMIC REFLECTION LINES
USED IN ANALYSIS

JOB NO. MV9600

FIGURE 9-3

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED ______ DATE ______
REVISED DWK DATE 12/18/80
REVISED UDap DATE 11/20/81
APPROVED GHF DATE 12/30/80

T-1344-2

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FIGURE 9-3

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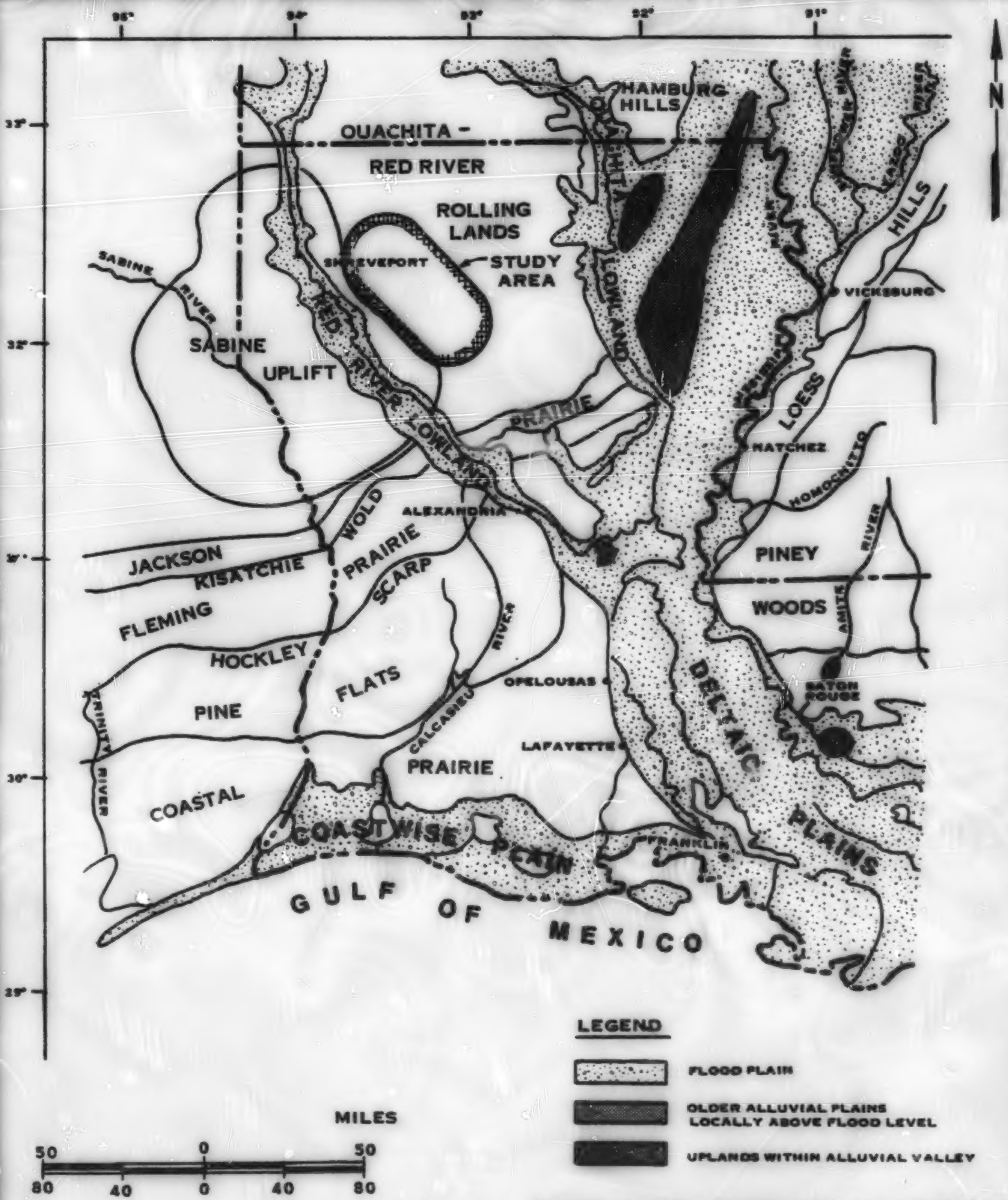

PHYSIOGRAPHY MODIFIED FROM FISK (1944), MURRAY (1961).

PREPARED [illegible] DATE [illegible]
REVISED [illegible] DATE [illegible]
REVISED ______ DATE ______
APPROVED GHF DATE 12/23/80

T-1346-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM

GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

NORTH LOUISIANA STUDY AREA

PHYSIOGRAPHIC MAP

JOB NO. MV 9600 FIGURE 9-4

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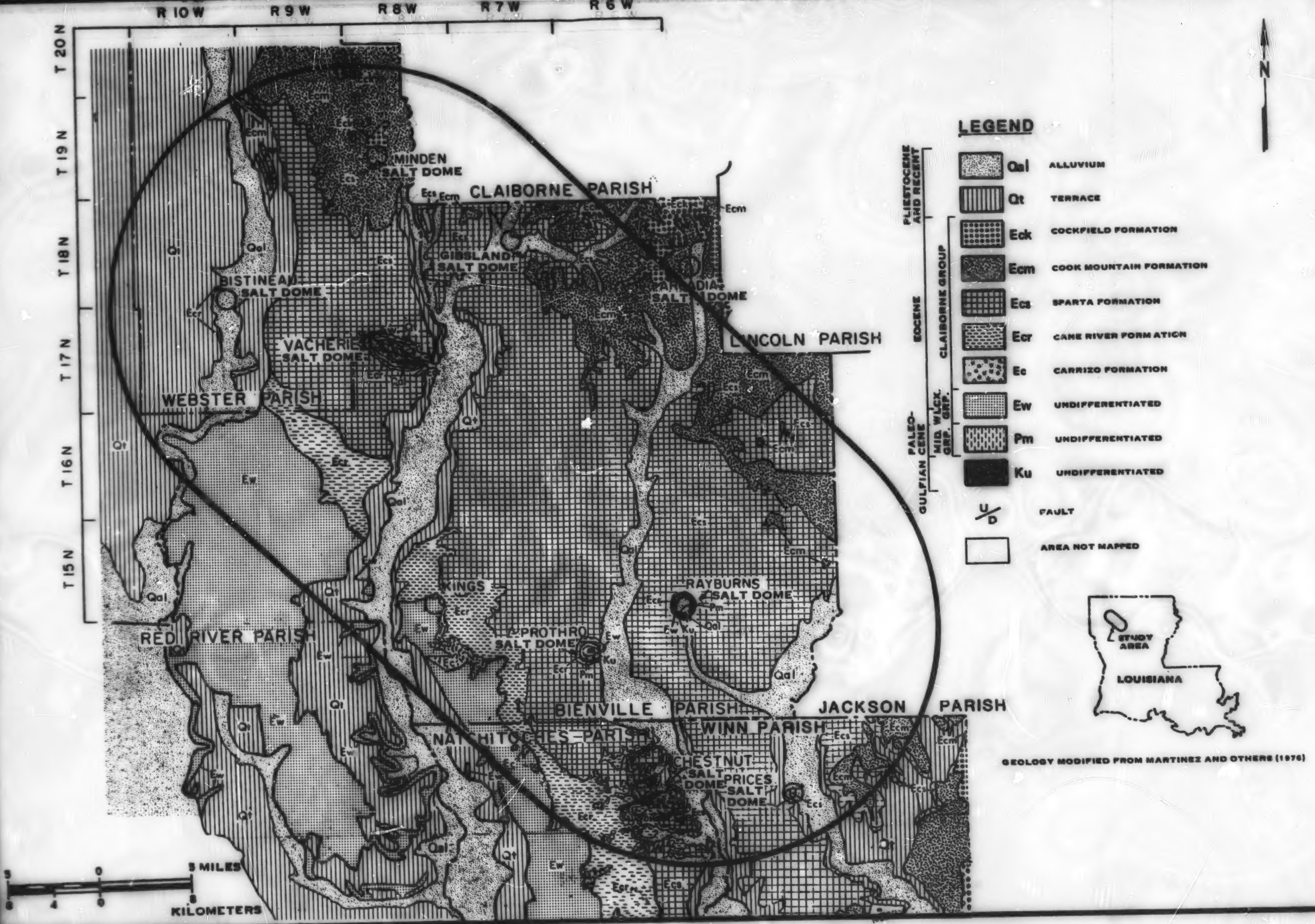
Black Lake Bayou, Saline Bayou, and the Dugdemona River, which flow to the south (Figure 9-2).

Southwest of this cuesta the exposed Sparta Formation is dissected by incised stream valleys. The general nature of the terrain is locally interrupted above some salt domes by circular or oval inliers of Upper Cretaceous, Gulfian and/or lower Tertiary formations, often partially surrounded by a Sparta cuesta with up to 61 meters (200 ft) of relief. Upper Cretaceous Gulfian and/or lower Tertiary formations overlie the salt at Vacherie and encircle a supradomal depression at Rayburn's, but most of the pre-Quaternary beds are covered by alluvial deposits.

A northwest-southeast trending, dissected cuesta, formed by the Sparta Formation, occupies the southern and southwestern part of the study area along the Sparta-Cane River contact (Figure 9-5). Elevations along the crest of the cuesta range from 110 to 122 meters (360 to 400 ft) above sea level, locally developing as much as 61 meters (200 ft) of relief (Figure 9-2). Relief along the Sparta cuesta decreases to the northwest so that the cuesta disappears west of Black Lake Bayou in T16N, R9W due to planation by the Red River during the Pleistocene Epoch.

The major streams occupy broad, steep-sided, flat-bottomed valleys. The range of relief between valley floors and upland areas is generally 30 to 46 meters (100 to 150 ft). The upland areas range in maximum elevations from over 152 meters (500 ft) above sea level in the northeastern section of the study area, to 107 to 122 meters (350 to 400 ft) in the southwestern and southern sections.



GEOLOGY MODIFIED FROM MARTINEZ AND OTHERS (1976)

NORTH LOUISIANA STUDY AREA
SURFACE GEOLOGIC MAP

JOB NO. MV9800

FIGURE 9-5

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED ________ DATE 12/18/80
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FIGURE 9-5

A series of fluviatile terraces, primarily related to Pleistocene Red River deposition and erosion, have been mapped in northwestern Louisiana by Fisk (1938, 1940), Murray (1948), Martin and others (1954), Jones (1960), and Kolb (1978, 1979). Terrace deposits are mapped along modern stream valleys, in the depressions over the salt domes, and, in some places, as a veneer on the upland areas (Figure 9-5). Lithologically, each terrace is composed of a gravelly substratum overlain by silt and clay. Fisk named the terraces, from highest and oldest to lowest and youngest, Williana, Bentley, Montgomery, and Prairie; however, correlation of the terraces from one area to another is controversial and unresolved. (See Volume I, Section 2.1, for a discussion of terrace formation.)

The older terraces, Williana and Bentley, were presumably formed by the Red River when it flowed in a wide valley that extended into central Bienville Parish a considerable distance east of its present flood plain. These terraces are well dissected by recent drainage or have been completely eroded from the upland areas they once covered.

The younger terraces, Montgomery and Prairie, were formed by the Red River and its tributaries. The Prairie Terrace, in particular, was mapped by early workers as flanking most tributary streams; however, it becomes indistinguishable from the modern flood plain in some headward areas (Martin and others, 1954).

An even younger terrace of probable late Pleistocene or early Holocene age, the Deweyville, has recently been identified in the

Gulf Coast Region, positioned only slightly above the present flood-plain level of streams. Kolb (1978, 1979) has tentatively mapped the Deweyville Terrace, or its age equivalent, flanking Black Lake Bayou and Bashaway Creek.

However, neither the geologic processes nor the history of the formation of Pleistocene river terraces in the study area are completely understood. A survey of the pertinent literature shows that the identification, correlation, and dating of various terrace levels in different parts of the Mississippi, Red, and Ouachita River Basins are in dispute (Kolb 1979; Durham and others, 1967; and Doering, 1956). For example, comparison of Bossier and Webster Parish geologic maps (Jones, 1960; Martin and others, 1954) reveals discrepancies in terrace correlation along the common boundary. Dome-related processes, which may have interacted to produce the terraces along small tributaries, such as Bashaway Creek, may yet be deduced from further analysis of the nature and distribution of terraces within salt dome areas.

9.2.2 STRATIGRAPHY: The depositional history of the North Louisiana Study Area, from the Mesozoic through the Cenozoic, consists of a series of depositional cycles, each transgressive at the base, inundative in the middle, and regressive at the top. Each stratigraphic stage represents a depositional cycle, from the Late Triassic Eagle Mills through the Eocene Claiborne (see Table 9-1 for the stratigraphic column of the study area). The Jurassic and Early Cretaceous cycles (except for the Coahuilan) are the most completely developed, and the Cotton Valley can even

[redacted]

TABLE 9-1

NORTH LOUISIANA STUDY AREA
STRATIGRAPHIC COLUMN

ERA	SYSTEM	SERIES	STAGE/ GROUP	FORMATION	THICKNESS RANGE (FEET)	LITHOLOGY
CENOZOIC	QUATERNARY	RECENT		ALLUVIUM	10-25	GRAVELS, SANDS, SILTS AND CLAYS.
		PLEISTOCENE		TERRACE DEPOSITS	50-125	FLUVIAL SEQUENCES OF GRAVEL, SAND, SILT AND CLAY.
	TERTIARY	EOCENE	CLAIBORNE	COCKFIELD	10-40	MASSIVE TO CROSS-BEDDED, GLAUCONITIC AND NON-GLAUCONITIC QUARTZ SANDS WITH INTERBEDDED SILTS AND CLAYS, FOSSILS, AND PLANT MATTER.
				COOK MOUNTAIN	60-300	FOSSILIFEROUS, GLAUCONITIC, CLAY IRONSTONE INTERBEDDED WITH CHOCOLATE BROWN CLAY AND SILTY SANDS.
				SPARTA	300-810	MASSIVE, FINE GRAINED, CROSS-BEDDED SANDS INTERBEDDED WITH SANDY CLAYS, CONTAINS OCCASIONAL LIGNITES, FOSSILS AND DISULFIDES.
				CANE RIVER	120-465	LOWER, KHAKI-COLORED, INTERBEDDED SILT AND CLAY UNIT; MIDDLE GLAUCONITIC, FOSSILIFEROUS MARL; AND AN UPPER CLAY WITH SILT AND SANDY SILT.
				CARRIZO	50-150	FINE TO COARSE GRAINED, FELDSPATHIC, GLAUCONITIC, MASSIVE SANDS WITH MINOR AMOUNTS OF CLAYS, SILTS AND LIGNITES.
			WILCOX	UNDIFFERENTIATED	480-1145	DELTAIC SEQUENCE OF SANDS, SILTS, CLAYS AND LIGNITES WITH INTERBEDDED MARINE SANDS AND CLAYS. COMMONLY CONTAINS GLAUCONITE.
		PALEOCENE	MIDWAY	UNDIFFERENTIATED	420-845	DARK GRAY TO BLACK, PLATY, MICACEOUS, FOSSILIFEROUS, LIGNITIC, CARBONACEOUS SHALE GRADING UPWARD INTO SAND.
MESOZOIC	CRETACEOUS	GULFIAN	NAVARRO	ARKADELPHIA	20-225	PREDOMINANTLY A CHALKY MARL WITH A LARGE AMOUNT OF INTERBEDDED SHALES AND CLAYS.
				NACATOCH	50-600	MARLS AND CHALKS GRADING UPWARD INTO MARLS AND MASSIVE, GLAUCONITIC CALCAREOUS SANDS WITH A FEW SHALE BEDS.
				SARATOGA	30-120	TWO WHITE TO GRAY, FOSSILIFEROUS, SLIGHTLY ARENACEOUS AND ARGILLACEOUS, GLAUCONITIC CHALK BEDS SEPARATED BY A THIN SHALE BED.
			TAYLOR	MARLBROOK	95-650	GRAY, CHALKY CLAY INTERBEDDED WITH MARL AND SHALE.
				ANNONA	35-165	WHITE TO GRAY, CALCAREOUS, FOSSILIFEROUS CHALK WITH SOME INTERBEDDED CALCAREOUS, MICACEOUS SHALE.
				OZAN	60-285	PREDOMINANTLY A LIGHT GRAY TO BROWN GRAY MARL WITH SOME INTERBEDDED SHALE.
			AUSTIN	BROWNSTOWN	500-875	MASSIVE, FINE TO MEDIUM-GRAINED SANDSTONES WHICH ARE SOMETIMES INTERBEDDED WITH GRAY SHALES.
				TOKIO		CHALKS AND MARLS GRADING UPWARD INTO MARLY, SILTY SHALES; SANDS, AND SOMETIMES CHERT GRAVELS.
			EAGLEFORD	EAGLE FORD	20-75	DARK GRAY, MICACEOUS, SILTY SHALE WITH THIN LENSES OF FINE-GRAINED SANDSTONES; CONTAINS THIN INTERBEDDED LIMESTONES TO THE SOUTH.
		UPPER	WOODBINE/ TUSCALOOSA	TUSCALOOSA (UPPER, MIDDLE, AND LOWER)	100-600	MASSIVE SANDSTONE OVERLAIN BY A DARK, CALCAREOUS SHALE UNIT AND AN UPPER INTERBEDDED SANDSTONE AND SHALE UNIT.
		LOWER COMANCHEAN	WASHITA	UNDIFFERENTIATED	330-1650	MEDIUM TO DARK GRAY SHALES, FLAGGY LIMESTONES, INTERBEDDED SHALES AND LIMESTONES, AND MINOR AMOUNTS OF SAND.
			FREDERICKSBURG	GOODLAND	100-400	CHALKY, WHITISH LIMESTONE ALTERNATING WITH CALCAREOUS CLAY AND SHALE; SOMETIMES CONTAINS SAND; BECOMES LESS CLASTIC, MORE CALCAREOUS UPWARD.
				PALUXY	40-600	RED, BROWN AND GRAY SHALES WITH A FEW INTERBEDDED MASSIVE PINK, GRAY, AND WHITE SANDSTONES.
			TRINITY	RUSK FM. [illegible]	400-1500	FINE GRAINED, GRAY TO BROWN SHALES AND SANDSTONES WITH A FEW INTERBEDDED LIMESTONES INCREASING IN ABUNDANCE SOUTHWARD.
				RUSK FM. [illegible]		GRAY TO BROWN, DENSE TO FINELY CRYSTALLINE, LIMESTONE INTERBEDDED WITH SMALL AMOUNTS OF DARK GRAY TO BLACK SHALE AND STRINGERS OF MICACEOUS SANDSTONE.
				FERRY LAKE	100-650	GENERALLY A WHITE, MASSIVE ANHYDRITE WITH SMALL AMOUNTS OF SHALE AND DOLOMITIC LIMESTONE.
				RODESSA	300-700	WHITE TO DARK GRAY, FOSSILIFEROUS LIMESTONE WITH OOLITIC ZONES; INTERBEDDED WITH MEDIUM TO COARSE GRAINED SANDSTONE AND DARK GRAY CALCAREOUS SHALE.
				JAMES	300-600	GRAY TO BROWN LIMESTONES WITH INTERBEDDED GRAY TO BLACK SHALE; CONTAINS A MASSIVE OOLITIC, COQUINOID, OR EARTHY LIMESTONE FACIES IN SOME AREAS.
				PINE ISLAND	75-160	DARK GRAY TO BROWNISH BLACK SPLINTERY SHALE WITH THIN BEDS OF LIMESTONE AND LIMY SHALE.
			COAHUILA	SLIGO	300-600	LIGHT TO DARK GRAY AND BROWN, FOSSILIFEROUS SHALES, LIMY SHALES, AND SANDY, ARGILLACEOUS OR OOLITIC LIMESTONES.
				HOSSTON	1550-3570	LOWER SANDSTONES INTERBEDDED WITH GRAY SHALES; MIDDLE INTERBEDDED RED SHALES, AND SILTS; UPPER GRAY SHALES AND SANDS.
	JURASSIC	UPPER JURASSIC	COTTON VALLEY	DORCHEAT	1000-1700	MASSIVE SANDS INTERBEDDED WITH DARK SHALES; LIMESTONES; VERY FOSSILIFEROUS THINLY BEDDED LIMESTONES, SANDS, AND SHALES; AND CALCAREOUS SANDSTONES AND SHALES.
				SHONGALOO	300-1200	DARK GRAY LIMESTONES, SHALES, AND SANDSTONES.
				BOSSIER	300-600	DARK GRAY TO BLACK SHALES WITH LENSES OF DARK GRAY, THIN-BEDDED LIMESTONE.
			LOUARK	HAYNESVILLE FM. [illegible]	300-900	LAYERS OF DARK-GRAY SHALE AND FINE TO MEDIUM GRAINED, SILTY TO SHALY, WHITE, LIGHT GRAY, AND TAN SANDSTONE, AND SILTSTONE.
				HAYNESVILLE FM. BUCKNER MEMBER		LAYERS OF GRAY SHALE WITH GRAY, FINE TO MEDIUM GRAINED, ARGILLACEOUS, SABINAL LIMESTONES.
				SMACKOVER	600-1000	DARK GRAY SHALE INTERBEDDED WITH A THIN, DARK GRAY SILTY TO ARGILLACEOUS LIMESTONE, AND OCCASIONALLY, CALCAREOUS SANDSTONE OVERLAIN BY A CLEAN LIMESTONE.
				NORPHLET	15-150	PRIMARILY REDBEDS WITH SOME GRAY, LACUSTRINE OR LAGOONAL SANDSTONES WITH A FEW THIN DOLOMITES AND SHALES.
		LOWER TO MIDDLE JURASSIC	LOUISIANA	LOUANN SALT	300-2600	WHITE, SMOKY GRAY OR CLEAR, COARSELY CRYSTALLINE HALITE WITH THIN BEDS OF ANHYDRITE.
				WERNER	150-460	LOWER CLASTIC MEMBER OVERLAIN BY AN ANHYDRITE MEMBER WITH MINOR AMOUNTS OF CARBONATE.
	TR	UPPER TRIASSIC		EAGLE MILLS	200-7000	RED AND WHITE SANDSTONES; RED AND BROWN SILTSTONES; RED, GREEN AND GRAY SHALES; AND VARICOLORED NODULAR DOLOMITES.

REFERENCE: ANDERSON, 1979

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be considered a supercycle because it contains three such depositional cycles. Development of the Coahuilan cycle was less clearly defined due to a high rate of clastic influx. Cyclic development during the Late Cretaceous was also somewhat masked by the realignment of structural features, caused by the rise of the Monroe and Sabine Uplifts and the subsidence of the Mississippi Embayment.

Nearly 6,096 meters (20,000 ft) of sediments make up the stratigraphic section from the Upper Triassic Eagle Mills Formation, through the Cretaceous, the Tertiary, and the Quaternary alluvium. In addition to reflecting depositional cycles, the geologic history of the study area was naturally influenced by the major structural features in the North Louisiana Syncline, a subsurface structural feature which has no surface expression. The structural axis of the North Louisiana Syncline trends northwest-southeast from near the Arkansas-Louisiana boundary to the western part of Grant Parish in north-central Louisiana (Figure 9-6). The syncline lies between the Sabine Uplift on the west and the Monroe Uplift and D'Arbonne Platform on the east. The two uplifts were important sources of sediment briefly during the Cretaceous, but the major, long-term clastic sources were the Appalachian Mountains and high areas to the north, drained by the Mississippi River and streams draining southwestward from the Appalachian System.

The North Louisiana Syncline encompasses three major structural features that are significant to the regional distribution of these sediments (Figure 9-7). The northernmost of these is

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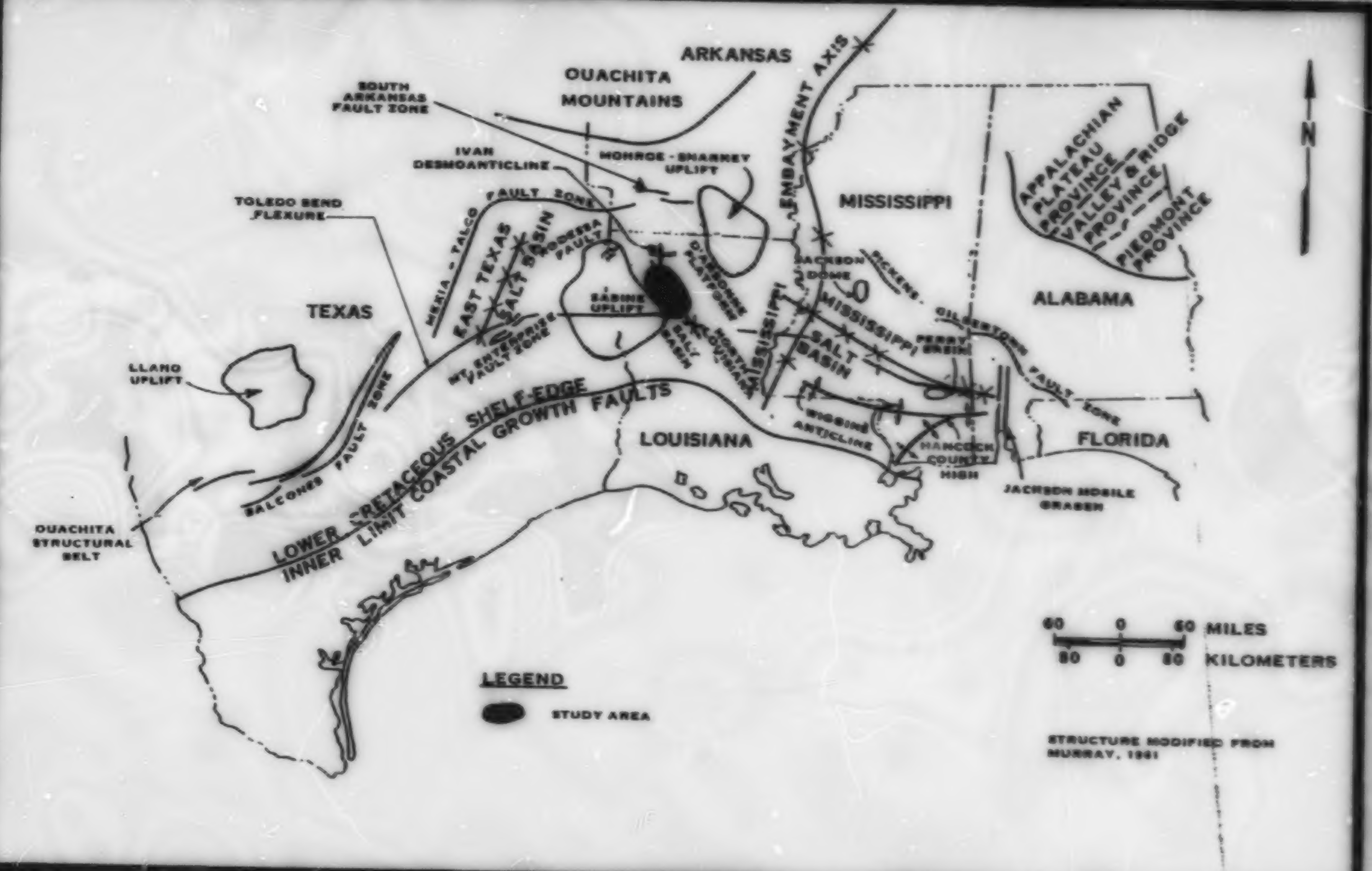

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

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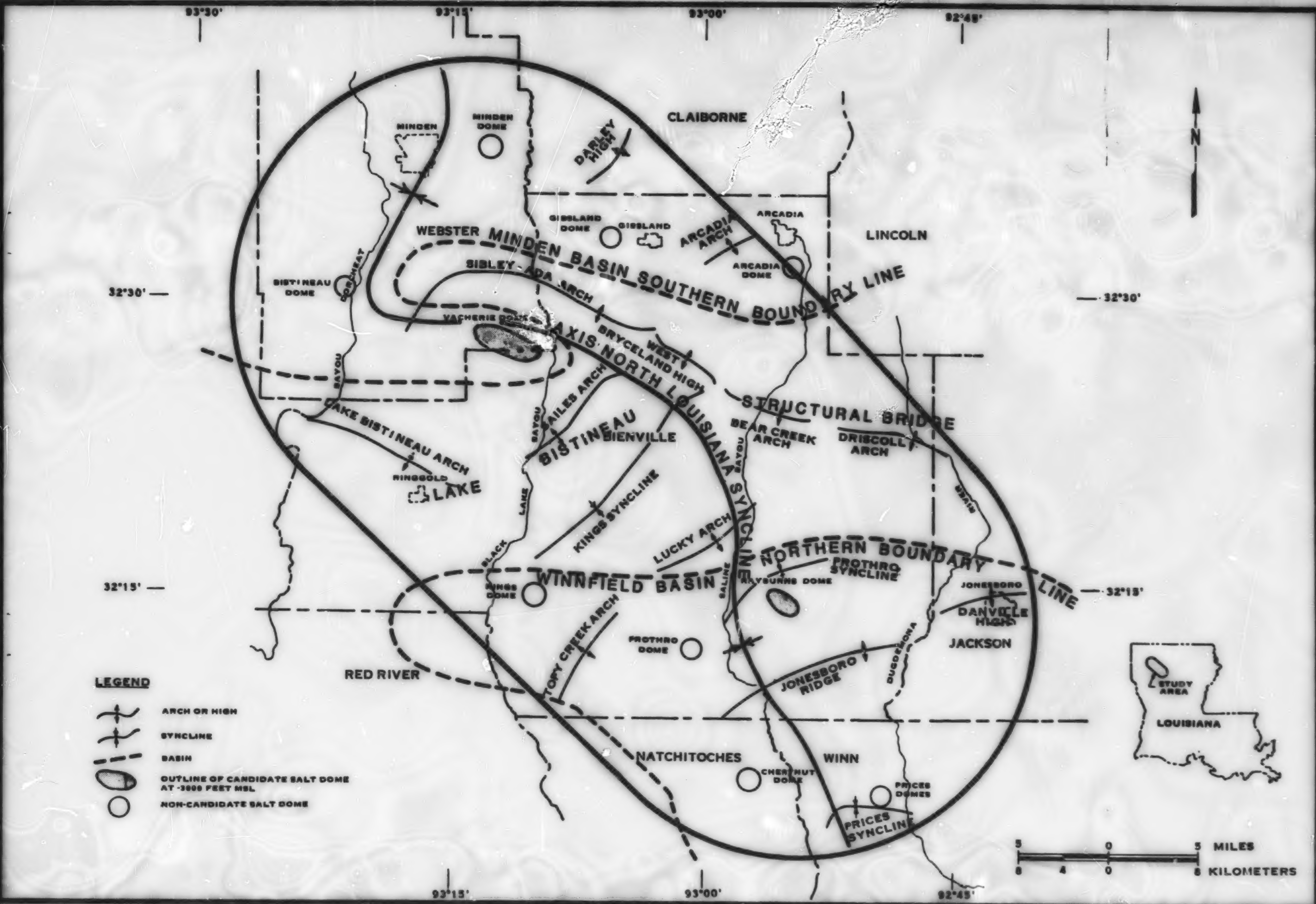
NORTH LOUISIANA STUDY AREA
GULF COAST REGIONAL
STRUCTURAL FEATURES MAP

JOB NO. MV9600

FIGURE 9-6



NORTH LOUISIANA STUDY AREA
SUBSURFACE
STRUCTURAL FEATURES MAP

JOB NO. MV9600

FIGURE 9-7

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

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FIGURE 9-7 [redacted]

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the Minden Basin, a sinuous feature which encompasses five salt domes, including Vacherie. The Winnfield Basin is another negative feature which, like the Minden Basin, has a fairly complex outline but contains fourteen salt domes, including Rayburn's. The Lake Bistineau Structural Bridge is a positive feature which trends roughly east-west, connecting the Monroe and Sabine Uplifts, and separating the Minden and Winnfield Basins. There are no shallow-piercement salt domes associated with this feature. The North Louisiana Study Area includes part of the Lake Bistineau Structural Bridge, the northern portion of the Winnfield Basin, and all of the Minden Basin (Figure 9-7).

Bordering the Winnfield Basin on the south is the Toledo Bend Flexure, a positive feature which, although outside the study area, should nevertheless be mentioned because of its effect on sedimentation. During the Early Cretaceous, its crest was the site of the Stuart City Rudistid* Reef Complex which apparently flourished during the Trinity interval. The reef was so extensive that it interfered with normal circulation of marine waters, transforming northern Mesozoic shelf areas into a vast evaporite pan in which the Ferry Lake Anhydrite, and the upper anhydrite and lower anhydrite stringers of the lower Rusk and upper Rodessa Formations, were deposited (Anderson, 1979). The Lake Bistineau Structural Bridge also affected sedimentation by diverting it in an east-to-west direction rather than gulfward. Many stratigraphic units, such as the Ferry Lake and Eagle Ford Formations, reflect the major structural features by thickening in the two basins and thinning over the bridge. Differences in the three areas are also apparent in facies changes in the Dorcheat, Sligo, James, and Rodessa Formations, with typical basin lithologies in one or both of the basins, and bank, reef, or shoal-water facies across the bridge.

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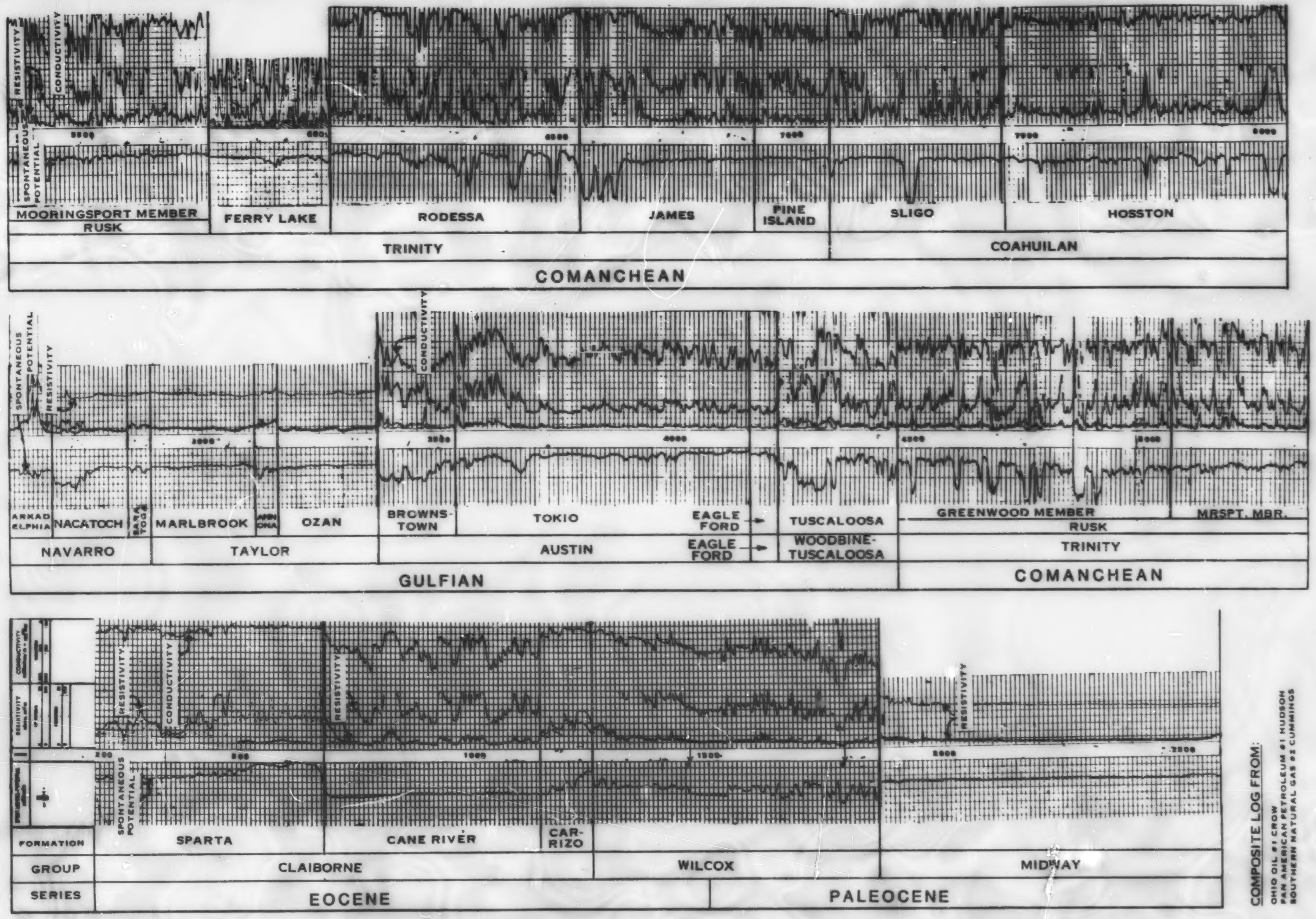
* Shoal marine deposits of the shells of bivalve mollusks which grew in large masses to form extensive reefs.

The following part of the report describes the lithology and the depositional history of the stratigraphic section from the Upper Triassic Eagle Mills Formation to the top of the Quaternary alluvium. Figure 9-8 is a composite geophysical log for the study area.

9.2.2.1 Triassic System, Upper Triassic Series: The Upper Triassic Series is represented by the Eagle Mills Formation, which is a continental deposit probably of alluvial origin. Presumably it underlies the entire Mesozoic shelf of the northern Gulf Coast Region. Its presence in the subsurface of the study area is suggested by the fact that it was encountered in the southern part of the Cotton Valley Field to the north. In this well the lithology of the Eagle Mills consists of red and white sandstones; dark red siltstones; silty shales and clay shales; and varicolored, nodular dolomites. Toward the base of the formation occur inclusions of angular mudstone fragments enclosed in siltstone or sandstone (Anderson, 1979). The Eagle Mills often contains evidence of igneous activity, such as dikes and sills of diorite, diabase, basalt, and detrital gabbros. The Eagle Mills Formation ranges in thickness from a minimum of 61



COMPOSITE LOG FROM:

OHIO OIL #1 CROW
PAN AMERICAN PETROLEUM #1 HUDSON
SOUTHERN NATURAL GAS #2 CUMMINGS

NORTH LOUISIANA STUDY AREA
COMPOSITE GEOPHYSICAL LOG

JOB NO. MV9600

FIGURE 9-8
(PAGE 1 OF 2)

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 9-8

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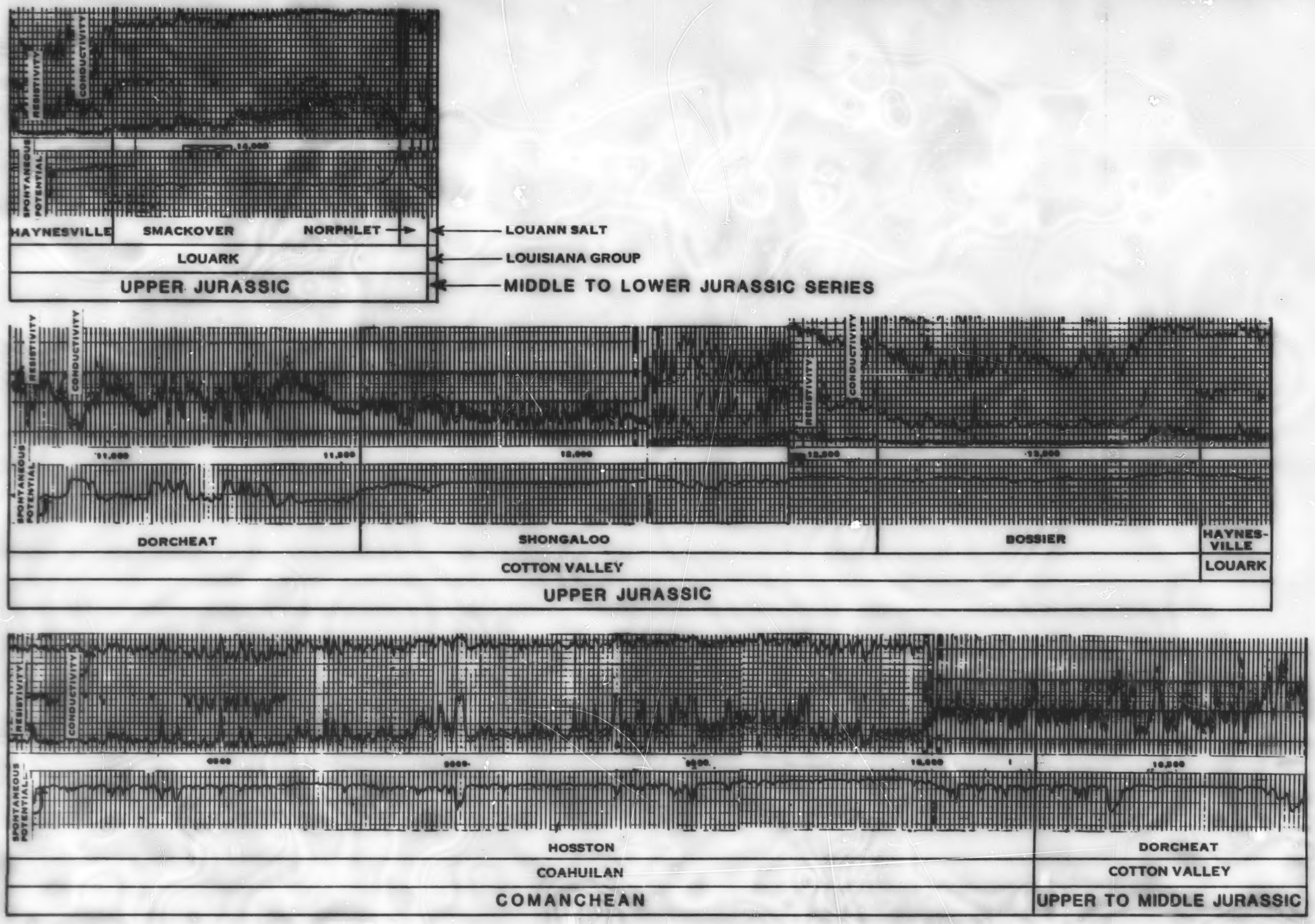

NORTH LOUISIANA STUDY AREA
COMPOSITE GEOPHYSICAL LOG

JOB NO. MV9600

FIGURE 9-5
(PAGE 2 OF 2)

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
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FIGURE 9-

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meters (200 ft) to a maximum of nearly 2,134 meters (7,000 ft). An angular unconformity separates the Eagle Mills from various underlying Paleozoic strata; the Eagle Mills is unconformably overlain by the Lower Jurassic Werner Formation.

9.2.2.2 Jurassic System, Lower Jurassic to Upper Jurassic* Series: The Lower Jurassic to Upper Jurassic Series includes, in ascending order, the Louisiana**, Louark, and Cotton Valley Stages/Groups.

9.2.2.2.1 Louisiana Stage/Group - The Louisiana Stage/Group, representing an abruptly terminated evaporitic cycle, is composed of the Werner Formation and the overlying Louann Salt. The scarcity of deep wells in gulfward areas limits the data and the interpretation of regional facies patterns of the Werner Formation. It is known in the subsurface of the study area in only one well in the southern part of the Cotton Valley Field to the north, just outside the study area. Presumably it underlies the entire Mesozoic Shelf of the northern Gulf Coast Region. The Werner is a marginal marine to continental deposit consisting of a lower clastic member that sometimes contains red beds, and an upper anhydritic member that also contains small amounts of carbonates. No lithologic data are available for the study area, but the formation is known to the north in Arkansas. There, the lithology of the Lower Werner is highly variable, reflecting the rock composition of the terrain over which the Werner seas transgressed. The Lower Werner lithology varies from conglomerates of diabase pebbles in a red shale matrix (probably from occasional occurrences of igneous material in the Eagle Mills), to red shales, mudstones, siltstones, and sandstones, similar to the underlying Triassic Eagle Mills red beds. The Upper Werner is less variable and, in the type well, consists of interbedded thin clastics, limestones, and dolomites at the base, grading upward into relatively pure, clear to white or smoky-gray, granular anhydrite, which comprises most of the unit. The Werner Formation varies in thickness from 46 meters (150 ft) to an unusual extreme of 140 meters (460 ft), and is conformably overlain by the Louann Salt.

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* Upper Jurassic units in the Gulf Coast Region have been designated by some authors as the Sabinas Series on the basis of excellent exposures in the Sabinas Basin of northeast Mexico. Murray (1961) suggested the term be extended throughout the coastal area on the basis of paleontological zoning. Such an extension would place the Norphlet, Smackover, and Haynesville Formations in the Zuloaga Stage of the Sabinas Series, and the Bossier, Shongaloo, and Dorcheat Formations in the overlying La Casita Stage of the series. Some authors feel that this areal extension ignores the stratigraphic utility of the Louark and Cotton Valley Groups. For the purpose of this report the term "Sabinas Series" has not been adopted; instead, the commonly used term "Late Jurassic Series" has been applied where appropriate.

** Term proposed by E. G. Anderson (1979) to include the Werner and Louann Salt Formations.

[redacted]

The Louann was presumably deposited in a marginal marine basin with restricted access to the open sea. The anhydrite content of the salt increases as the unit thins to 152 meters (500 ft) or less, particularly on the Monroe and Sabine Uplifts (Anderson, 1979). The Louann Salt is clear, white, or smoky-gray and coarsely crystalline (Crowe, 1975), and contains anhydrite in very thin laminae. An average thickness of 914 meters (3,000 ft) is generally assigned to the Louann in interior salt basins of the Upper Gulf Coastal Province to account for the volume of salt known and inferred to be present in shallow piercement and deep-seated, nonpiercement domes and ridges. The thickest section penetrated by any well is approximately 1,097 meters (3,600 ft); this well is situated immediately north of the study area in the Cotton Valley Field. The contact between the Louann and the overlying Louark Group is unconformable.

9.2.2.2.2 Louark Stage/Group - The Louark Stage/Group is composed of the Norphlet, Smackover, and Haynesville Formations. The Norphlet is a continental deposit composed of fluvial sediments grading southward to lacustrine and lagoonal clastic deposits; the formation consists primarily of red beds with some interbedded gray sandstones, a few thin dolomites, and shales. It is generally from 5 to 46 meters (15 to 150 ft) thick, and is conformably overlain by the Smackover.

The Smackover Formation in the study area is a basinal marine deposit consisting of three units: a lower limestone-rich unit, middle dominantly clastic unit, and an upper limestone-rich unit. The clastic unit is predominant in the study area. The Smackover ranges from 183 to 305 meters (600 to 1,000 ft) thick; the unit is conformably overlain by the Haynesville Formation.

The Haynesville consists of two members, the basal Buckner member and the Upper Haynesville member. According to Anderson (1979), the typical Buckner lithology (evaporitic, lagoonal, or back-barrier red sandstones, shales, siltstones, and anhydrites) is not found in the study area, but is represented here by its offshore marine equivalent, composed of gray shales, and gray, medium to fine-grain, argillaceous, basinal limestones. The Upper Haynesville member consists of dark gray to dark red shales, and fine to medium-grain, silty to shaly, white to light gray and pink sandstone. The entire Haynesville Formation varies from 107 to 274 meters (350 to 900 ft) thick within the study area, and may attain thicknesses in excess of 610 meters (2,000 ft) to the north. The Haynesville is unconformably overlain by the Cotton Valley Group (Berryhill, and others, 1968).

9.2.2.2.3 Cotton Valley Stage/Group - The Cotton Valley Stage/Group consists of the Bossier, Shongaloo, and Dorcheat Formations. In the study area, the Bossier is an offshore marine unit consisting of dark gray and black shales with thin lenses of dark gray limestone (Crowe, 1975). The contact with the overlying Shongaloo is conformable and the Bossier varies from 91 to 274 meters (300 to 900 ft) thick.

The Shongaloo Formation is an offshore unit composed of dark gray, fossiliferous limestones, shales, and sandstones. The Shongaloo is from 274 to 366 meters (900 to 1,200 ft) thick but locally may exceed 610 meters (2,000 ft); it is conformably overlain by the Dorcheat Formation.

The Dorcheat Formation consists of a lower, offshore facies and an upper, nearshore facies. In the Minden Basin the offshore facies is composed of interbedded blanket sands; medium gray and black, locally fossiliferous shales; and limestones (Sloane, 1958). Along the Lake Bistineau Structural Bridge (Figure 9-7), this lower, offshore facies becomes more arenaceous than in the Minden Basin and is dominated by a massive bar-sand facies. This sand grades southward into a basin shale facies which is characteristic of the Winnfield Basin (Echols, 1965). The upper, nearshore facies of the Dorcheat consists of three units: a limestone bed (the Cotton Valley Lime); a thinly interbedded unit consisting of limestones, gray, fossiliferous shales, and calcareous sandstones; and an uppermost regressive unit consisting of light-gray shales and sands. The Dorcheat Formation commonly varies from 305 to 366 meters (1,000 to 1,200 ft) in thickness, but locally may exceed 518 meters (1,700 ft). It is disconformably overlain by strata of the Lower Cretaceous Coahuila Group.

9.2.2.3 Cretaceous System, Comanchean Series: The Comanchean Series in the study area is represented by the Coahuila*, Trinity, Fredericksburg, and Washita Stages/Groups.

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*The Coahuila(n) has been termed a "group" by some authors and a "stage" by others. It has also been called both a "series" and a "stage" by various authors. Because it is bounded below by the Cretaceous/Jurassic disconformity and above by the top of the Three-Finger Limestone of the Sligo Formation, it is considered a valid time-stratigraphic unit, and, is therefore termed a "stage." Anderson (1979) has stated that the magnitude of the Coahuila(n) in the subsurface is comparable to that of the overlying Trinity and, like the Trinity, the Coahuila(n) comprises a sedimentary cycle. For these reasons, Barrow's (1953) proposal -- that the Coahuila be considered one of four cycle-based stages included in the Comanchean Series, and not a separate series -- has been adopted in this report.

9.2.2.3.1 Coahuila Stage/Group: The Coahuila Stage/Group is composed of the Hosston and overlying Sligo Formations. The Hosston Formation in the northern part of the study area consists of four units. The basal member is dominated by an upward fining sequence of interbedded sandstones and red to gray shales; the second member is made up largely of interbedded gray to red sandstones and red shales; the third member is dominated by red shales and siltstones; the uppermost member comprises an upward-fining sequence of alternating sands and shales which change from red to gray upward, and grade into and inter-tongue laterally with basal calcareous strata of the Sligo Formation. All members change southward in the study area from predominantly red beds to gray shales with minor amounts of red beds. There is also a decrease in grain size, from north to south, evidenced by a decrease in sand percentage and an increase in shale content in the Winnfield Basin (Anderson, 1979). The Hosston ranges from 472 to 1,088 meters (1,550 to 3,570 ft) in thickness.

The Sligo Formation is composed of alternating beds of gray, calcareous shale, and dense limestone (Echols, 1965). The marine clastic units are more strongly developed in the lower part of the Sligo, making the gradational contact with the Hosston Formation difficult to pick because of the similarity in electric-log signature (Figure 9-8). The Sligo commonly contains a localized reef, shoal, or bank facies called the Pettet Zone. The Pettet is particularly well-developed on the Lake Bistineau Structural Bridge, and is generally porous where oolitic and fossiliferous.

[redacted]

It is also oolitic, and therefore more porous along other positive structures in the study area (Anderson, 1979). The Three-Finger Limestone marking the top of the Sligo on electric logs is commonly used as a subsurface marker (Figure 9-8). In both basin areas, the Sligo consists primarily of limestones and shales. The formation varies from 91 meters (300 ft) to more than 183 meters (600 ft) thick in the study area, and is conformably overlain by the Trinity Group.

9.2.2.3.2 Trinity Stage/Group - The Trinity Stage/Group is composed of the Pine Island, James, Rodessa, Ferry Lake, and Rusk Formations. The Pine Island is a marine shelf deposit consisting primarily of dark, splintery, calcareous shale. In some areas it contains thin beds of argillaceous limestones or limy shales (Crowe, 1975). The Pine Island is from 23 to 49 meters (75 to 160 ft) thick and is conformably overlain by the James Formation.

In the Minden Basin, the environment of deposition for the James was a mildly unstable shelf with biostromes developed locally. Here, the James is characterized by white chalky and light gray, sugary limestones with abundant fossil fragments, oolites, and calcareous sand grains. As can be seen on the composite log (Figure 9-3), similarities in lithology make it very difficult to distinguish the James from the overlying Rodessa in this area (Echols, 1965).

In the Winnfield Basin, however, the James Formation is lithologically more distinctive. It was deposited in a deep-water, basinal environment and consists of an interbedded limestone and shale unit with minor amounts of sandstone. The James also contains a shallow-water facies which is particularly well-developed along the Lake Bistineau Structural Bridge. It is generally a hard, massive, crystalline limestone but in some areas becomes oolitic, coquinoid, or even earthy. Since this facies is deposited only in shallow water, it "followed" the gulfward regression of the nearshore environment, and thus appears at different points vertically through the formation, depending on the location of the well. The James Formation in the study area is 91 to 183 meters (300 to 600 ft) thick and is conformably overlain by the Rodessa Formation.

The Rodessa Formation is a marine deposit consisting of two facies: a basin facies and a shoal-water bank facies. The basin facies consists of dark, calcareous shale interbedded with dense limestones. The shoal-water bank facies, which is best developed over the Lake Bistineau Structural Bridge, consists primarily of varying amounts of granular and biogenic limestone; fossil fragments cemented by white, granular calcium carbonate; and interbedded dark shale. This facies is commonly oolitic and also contains anhydrite stringers in the upper portion. The bank facies changes southward, into the Winnfield Basin, into dense basin shales and limestones (Echols, 1965). The bank facies of the Rodessa Formation has not been traced into the Minden Basin. The Rodessa Formation, where distinguishable from the James, ranges in thickness from 91 to 213 meters (300 to 700 ft) and is conformably overlain by the Ferry Lake Formation.

The Ferry Lake Formation is an evaporitic deposit composed mainly of white anhydrite interbedded with gray shales and minor amounts of dense limestones. The lithology does not change appreciably within the study area. The base of the Ferry Lake is a reliable electric-log marker (Figure 9-8) and is often used as a mapping horizon (Figure 9-9). The thickness of the Ferry Lake Formation ranges from 30 to 198 meters (100 to 650 ft) and it is conformably overlain by the Rusk Formation.

The Rusk consists of the Mooringsport and Greenwood members. The lowermost Mooringsport member is predominantly a fossiliferous, gray to brown, dense to finely crystalline series of limestones with interbedded dark-gray shales and stringers of micaceous sandstone. In the Minden Basin the clastic components dominate, whereas in the Winnfield Basin the carbonates are thicker, more numerous, and may even be dominant (Anderson, 1979). The Mooringsport was presumably deposited in a somewhat deeper offshore environment than the overlying, shallow-water Greenwood member.

The Greenwood member of the Rusk consists of thinner carbonates than the Mooringsport and generally contains more clastics, especially sands (Figure 9-8). Like the Mooringsport, it is more clastic in the Minden Basin than in the Winnfield Basin. The Greenwood in the study area is composed predominantly of interbedded red shales and silts, tan to white sandstones of medium to fine-grain size, and thin gray limestones. Toward the top of the

Greenwood member, a sequence of thinly interbedded limestones and shales indicates a return to the low clastic-influx rate of the underlying Mooringsport. The nature of the contact between the Mooringsport and Greenwood members is variable. At some localities it is gradational, and at others it is erosional, the top of the Mooringsport having been channeled and filled with massive sands of the basal Greenwood (Echols, 1965). The thickness of the Rusk Formation ranges from 122 to 457 meters (400 to 1,500 ft) or more in the study area. Where the upper portions of the Rusk Formation and the Fredericksburg and Washita Groups have been removed by erosion, the Rusk Formation is unconformably overlain by beds of the Gulfian Tuscaloosa Group. Where no erosion of the interval has occurred, the Rusk Formation is conformably overlain by the Paluxy Formation of the Fredericksburg Group.

9.2.2.3.3 Fredericksburg Stage/Group - The Fredericksburg Stage/Group is composed of the Paluxy and Goodland Formations. The Paluxy is a regressive deposit composed primarily of varicolored to gray shales and silts, with some discontinuous sands (Echols, 1965). There is a general gulfward gradation from sands to shales and, in the Winnfield Basin, most of the sands disappear downdip. The presence or absence of the Paluxy Formation delineates the outline of the Lake Bistineau Structural Bridge due to the Sub-Gulfian Unconformity* between the Comanchean and Gulfian

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* The Sub-Gulfian Unconformity, also called the Upper Cretaceous-Lower Cretaceous Unconformity, refers to a major erosional episode which occurred between the Gulfian and Comanchean Series throughout most of the Gulf Coast Region.

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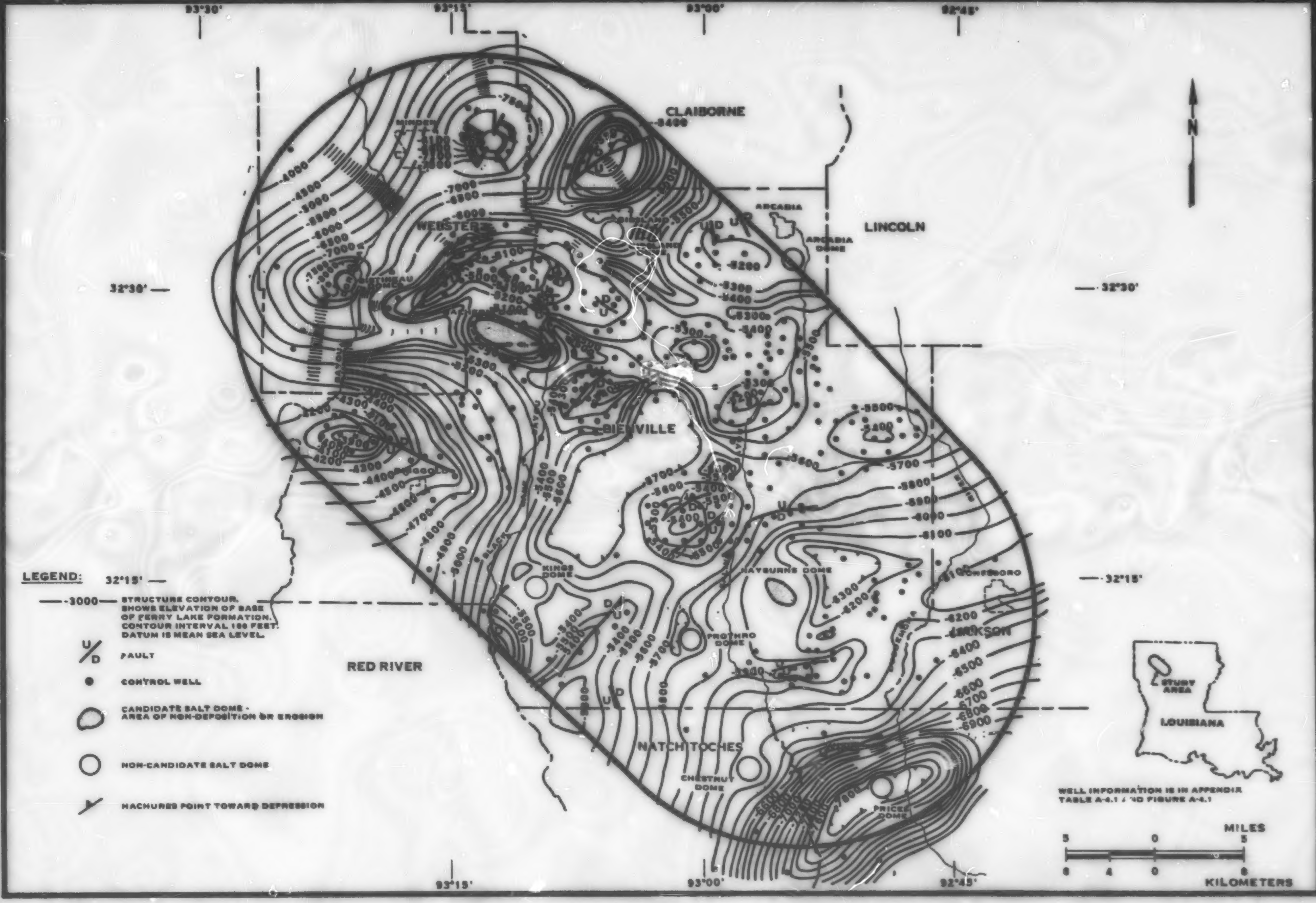

NORTH LOUISIANA STUDY AREA
STRUCTURAL CONTOUR MAP
BASE OF FERRY LAKE FORMATION

JOB NO. MV2880

FIGURE 9-9

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED Jmf DATE 12/12/80
REVISED DATE 11/20/81
REVISED DATE
APPROVED GHF DATE 12/23/80

T-1350-2

FIGURE 9-9

BEST DOCUMENT AVAILABLE

Series. The formation and overlying Comanchean beds were eroded over this feature but were preserved, at least in part, in most areas of the Minden and Winnfield Basins (Anderson, 1979). Because of the erosional unconformity at the top of the formation, the thickness of the Paluxy in the study area is highly variable and, where present, ranges from 12 to 152 meters (40 to 500 ft). The Paluxy is conformably overlain by the Goodland Formation.

The Goodland is dominantly a carbonate unit but does contain some interbedded shale and marl and, in near-source areas, some sand. The clastics are more common in the lower half of the formation, and characteristically grade upward into massive limestone. Under favorable conditions (as in Central Texas and on the Sabine Uplift) variable parts of the Goodland develop a bank facies known as the Edwards Limestone. The Goodland is generally absent on the Lake Bistineau Structural Bridge, having been eroded away, but it is present throughout large areas of the Minden and Winnfield Basins. There, the Goodland ranges from 30 to 122 meters (100 to 400 ft) and is conformably overlain by the Washita Stage/ Group.

9.2.2.3.4 Washita Stage/Group - The Washita Stage/Group, where fully developed, consists of the Kiamichi, Duck Creek, Fort Worth Denton, Weno-Paw Paw, Main Street, Grayson, Buda, and South Tyler/Dantzler Formations; however, in this report, the Washita has not been subdivided. In the study area the Washita Group consists of medium to dark gray shales, flaggy limestones, interbedded shales and limestones, and minor amounts of sand. Because of the differential erosion during subaerial exposure at the close of the Comanchean, the thickness of this open-marine deposit varies from 91 meters (300 ft) to as much as 549 meters (1,800 ft) in areas such as the Minden Basin (Anderson, 1979). The Washita Group is unconformably overlain by the Tuscaloosa Group of the Gulfian Series.

9.2.2.4 Cretaceous System, Gulfian Series: The Gulfian Series includes the Woodbine/Tuscaloosa, Eagle Ford, Austin, Taylor, and Navarro Stages/Groups.

9.2.2.4.1 Woodbine Stage/Tuscaloosa Group - The Tuscaloosa Group in the study area is divided into the Lower, Middle, and Upper Tuscaloosa Formations. The Lower (transgressive) Tuscaloosa, which consists of a massive sand, is thickest downdip in structurally low areas, and thins updip regionally and locally on structures. The Middle Tuscaloosa Formation, which is normally dominated by shales, picks up some sands within parts of the Minden Basin; hence, it becomes less clearly distinguishable from the Upper Tuscaloosa, which consists of interbedded sands and shales, and the Lower Tuscaloosa Formation. Along the eastern and northern flanks of the Sabine Uplift, an area which is distant from the sediment source, the Upper Tuscaloosa may be the only one of the three that is present, or it may be indistinguishable from the attenuated Middle Tuscaloosa. The Upper Tuscaloosa Sands thicken toward the Monroe Uplift and become

[redacted]

dominant in the Formation. Along the Lake Bistineau Structural Bridge the number of sand units in this formation increase. Within the study area the Tuscaloosa ranges in thickness from 30 to 183 meters (100 to 600 ft) and is conformably overlain by the Eagle Ford Stage/Group.

9.2.2.4.2 Eagle Ford Stage/Group - The Eagle Ford Stage/Group is represented in the study area by only one unit, the open-marine Eagle Ford Formation. The Eagle Ford is characterized here by a dark gray, micaceous, calcareous shale with a few beds of marl and sand. It thickens gradually northward from the Lake Bistineau Structural Bridge into the Minden Basin (Echols, 1965). It also thickens southward from the bridge into the Winnfield Basin, where it develops a few flaggy limestones (Anderson, 1979). The Eagle Ford ranges from 6 to 23 meters (20 to 75 ft) in thickness and is conformably overlain by the Austin Group.

9.2.2.4.3 Austin Stage/Group - The Austin Stage/Group comprises two marine units, the Tokio and the Brownstown Formations. The Tokio grades upward from chalks and marls to marly, silty shales, and finally, to sands. In some areas along the Lake Bistineau Structural Bridge, a coarse-clastic facies (gravel, usually chert) occurs at, or near, the top of the Tokio. Grain size and clastic ratios decrease gulfard.

The Brownstown Formation is distinctively developed along the Lake Bistineau Structural Bridge as an offshore-bar facies composed of massive, fine to medium-grain, calcareous, quartzose sandstones. This massive bar-sand breaks up across the Minden Basin into three sand tongues separated by gray shale beds. The sand tongues thin out, changing facies into shale inland to the north and northwest, some distance beyond the study area. The massive bar-facies along the bridge changes into a basin-shale facies within a relatively short distance gulfward across the Winnfield Basin. In its depositional character the Brownstown Formation is a remarkable analogue of the Upper Jurassic Dorcheat, demonstrating the durability of the bridge as a tectonic feature (Anderson, 1979).

The Rapides Shale is a rock unit which has been placed by many geologists in the Eagle Ford Formation. Forgotson (1958) determined that it was separated from the Eagle Ford by an unconformity and, therefore, the Rapides is now considered to be in the Austin Stage/Group. The type locality for the Rapides is in central Louisiana, where it attains a thickness of 76 meters (250 ft) and consists of a dark gray, micaceous shale with thin beds of glauconitic, calcareous shale; argillaceous, chalky limestone; and limestone. It is not used as a reference for mapping purposes in north Louisiana, however, because it has thinned greatly and is lithologically so similar to the underlying Eagle Ford that it can be distinguished only by paleonotological analysis.

The thickness of the Austin Stage/Group ranges from 198 to 296 meters (650 to 970 ft). It is conformably overlain by the Taylor Stage/Group.

9.2.2.4.4 Taylor Stage/Group - The Taylor Stage/Group is composed of the Ozan, Annona, and Marlbrook Formations. The marine

Ozan Formation consists largely of silty to sandy marl with interbedded thin siltstones and chalk. The marls and chalks are fossiliferous, and the siltstone is slightly glauconitic and pyritic. The Formation becomes increasingly dark gray and calcareous to the north, and the mica content of the marls increases, suggesting a clastic source to the south. In the eastern part of the study area, well-log data indicate a sand unit at the top and at the base of the Ozan, extending to the north, east, and southeast of the study area, suggesting a source in the Monroe Uplift (Echols, 1965). The Ozan ranges in thickness from 18 to 87 meters (60 to 285 ft) and is conformably overlain by the Annona.

The Annona Formation is a white to gray, fossiliferous, clayey chalk which was deposited in an open-marine environment. It contains some interbedded micaceous shales and ranges in thickness from 11 to 56 meters (35 to 185 ft) in the study area (Reese, 1977). It is conformably overlain by the Marlbrook.

The Marlbrook Formation, the uppermost unit of the Taylor Group, consists of a shelf sequence of light gray to olive, fossiliferous, micaceous marlstone with disseminated carbonaceous matter. Locally it is chalky and silty and contains scattered pyrite crystals. Although the Marlbrook generally becomes more calcareous gulfward, there is no major difference in its lithology in the Minden and Winnfield Basins (Echols, 1965). The Marlbrook ranges in thickness from 29 to 177 meters (95 to 580 ft) and is unconformably overlain by the Navarro Stage/Group.

9.2.2.4.5 Navarro Stage/Group - The Navarro Stage/Group is composed of the Saratoga, Nacatoch, and Arkadelphia Formations. The Saratoga has been placed by some stratigraphers in the Taylor Group on the basis of micropaleontologic evidence and a depositional break at its upper boundary (Hazzard and others, 1945; Drouant, 1960). Others have placed the Saratoga in the Navarro Group on the basis of a contrary paleontologic interpretation of macrofossils and evidence of an unconformity at its base (Stephenson, 1927; Dane, 1929). Kelly (1956) feels that the significance of the unconformity depends on the area being studied, and that if the Taylor-Navarro boundary were chosen on the basis of evidence in northwest Louisiana, the Saratoga-Marlbrook disconformity would be the logical choice. But, in the area studied by Dane and Drouant, the Saratoga-Nacatoch boundary represents the Taylor-Navarro. In this report the Saratoga is placed in the Navarro Group in light of the most recent work by Anderson (1979) and his interpretation of an unconformity at the base of the Saratoga. The Saratoga is a nearshore or shelf deposit and is composed of two white to gray, slightly arenaceous, clayey, fossiliferous, glauconitic chalk beds separated by a thin shale bed (Echols, 1965). The Saratoga Formation normally thickens southeasterly as well as gulfward; however, some abnormally thick sections have been penetrated by wells in the Minden Basin. Some of the gulfward thickening may be due to the addition of strata from above, i.e., basal Nacatoch beds that change facies southward from shale and marl into chalk similar to the Saratoga. The Saratoga is from 9 to 37 meters (30 to 120 ft) thick and is conformably overlain by the Nacatoch.

The typical sediments of the Nacatoch Formation were deposited in a shallow-shelf environment and consist of chalky marls grading upward into marl and massive, glauconitic, calcareous sands with interbedded shales. The sands change facies to marls and chalky marls southward and eastward in the study area. The entire formation contains disseminated carbonaceous matter, fossil fragments, and mica flakes. The Nacatoch is from 17 to 152 meters (55 to 500 ft) thick and is conformably overlain by the Arkadelphia Formation.

The lithology of the Arkadelphia Formation in the study area varies from a chalk to a chalky marlstone. Where it is chalk, it is predominantly white to light-olive gray or gray, with impurities of silt, sand, and clay. The chalk often contains embedded recrystallized fossils. Where it is a marlstone, it is light gray to light olive gray, very fossiliferous, and silty. Local decreases in calcium carbonate content change the lithology to that of a brownish-gray claystone. The Arkadelphia is an open-marine unit, is usually between 6 and 69 meters (20 and 225 ft) thick, and is disconformably overlain by the Paleocene Midway Stage/Group.

9.2.2.5 Tertiary System, Paleocene and Eocene Series: The Paleocene Series includes the Midway Stage/Group and the lower portion of the Wilcox Stage/Group. The Eocene Series is composed of the upper portion of the Wilcox Stage/Group and the Claiborne Stage/Group. Tertiary units above the Claiborne are not present in the study area due either to erosion or nondeposition.

9.2.2.5.1 Midway Stage/Group - The Midway Stage/Group is a marine unit and is undifferentiated in the subsurface of the study area. It consists of dark gray to black, platy, micaceous, fossiliferous, lignitic, and carbonaceous shales. The Midway becomes siltier and darker toward the bottom, and sandier and more calcareous toward the top where it intertongues with the overlying Wilcox Stage/Group (Figure 9-8). It ranges in thickness from 128 to 288 meters (420 to 945 ft).

9.2.2.5.2 Wilcox Stage/Group - The Wilcox Stage/Group, like the Midway, is undifferentiated in the subsurface of the study area. Overall, it is a deltaic sequence of fine- to medium-grain quartz sands interbedded with silts, shales, and lignites. Lateral changes are very abrupt, making it impossible to trace units over long distances. Glauconite and mica, typical of many deltaic deposits, are often found in the Wilcox. The Wilcox is locally very calcareous, at times consisting of silty, sandy limestone and occasional lenses of dolomitic limestone. The Wilcox Stage/Group thickens and becomes increasingly shaly and less sandy gulfward (Anderson, 1979). Thickness values range from an average of 149 to 349 meters (490 to 1,145 ft). The Wilcox is disconformably overlain by the Claiborne Stage/Group.

9.2.2.5.3 Claiborne Stage/Group - The Claiborne Stage/Group is composed of the Carrizo, Cane River, Sparta, Cook Mountain, and Cockfield Formations. The Carrizo Formation is a fine to coarse-grain, micaceous, glauconitic, feldspathic, massively bedded, quartz sand with minor amounts of interbedded clays and silts and some occasional lignite lenses (Echols, 1965). It weathers to a brick-red color and was deposited as valley and channel fills and beach sands. It was deposited over an erosional surface and, for this reason, varies greatly in thickness and does not extend over the entire study area. Where the Carrizo is absent, the Cane River rests disconformably upon the Wilcox. The Carrizo itself is disconformably overlain by the Cane River and is from 15 to 46 meters (50 to 150 ft) thick.

In the study area the Cane River Formation is a marine deposit consisting of a basal silt and clay unit, a middle marl, and an upper clay unit. The basal Cane River unit consists typically of thinly interbedded silts and clays which are tan-colored, micaceous, sandy, calcareous, glauconitic, fossiliferous, and pyritic (Figure 9-8). The middle Cane River unit is an extremely glauconitic, calcareous, fossiliferous marl. The upper Cane River unit is a clay with thin beds of silt and sandy silt. Leaf impressions and minor amounts of glauconite are sometimes found. Pyrite concretions are scattered throughout the formation, but they do not form notable accumulations. Thin, light to dark brown, cherty dolomite beds also occur. The dolomite is crypto-crystalline and very hard, embedding grayish olive-green or dark brown glauconite grains or quartz grains.

To the west and south of the study area, around the southern edge of the Sabine Uplift, the Cane River thins. However, around the northern edge of the Sabine Uplift, the Cane River thickens and is called the "undifferentiated lower Claiborne." The formation is composed of glauconitic clays and silts. Further west, toward the Texas state line, the formation picks up two distinctive sand lenses interbedded between the clays and silts. This breaks up the "undifferentiated lower Claiborne" into five units which can be correlated with several lower Claiborne Formations in Texas. The lower-most unit consists of glauconitic silts and clays and is equivalent to the Reklaw of Texas. The Reklaw itself may be present in the North Louisiana Study Area but, due to the similarity in lithology between it and the overall Cane River, it would be almost impossible to identify it on the basis of well logs alone. The overlying unit is comprised of two distinct sand layers and a glauconitic clay and silt bed which lies between them. This section is equivalent to the Queen City Formation of Texas. It thickens to the west but apparently pinches out to the east and is not recognized in the North Louisiana Study Area. The uppermost layer, which is equivalent to the Weches of Texas, is also a glauconitic clay and silt. This unit is equivalent to the Cane River of north Louisiana. The Cane River ranges in thickness from 37 to 142 meters (120 to 465 ft) in the study area and is conformably overlain by the Sparta Formation.

The Sparta Formation consists of two units. The lower unit is composed of white to light gray, predominantly fine-grain, massive, angular to subangular, marginal marine to deltaic quartz sands which contain small amounts of carbonaceous material, lignite, glauconite, pyrite, and fossil fragments (Figure 9-8). The upper unit consists of lagoonal or estuarine, medium gray, argillaceous silts interbedded with gray to brown, sandy, silty clays having thin beds of lignite, cherty dolomite, glauconite, and fossil casts and molds. The Sparta ranges in thickness from 91 to 186 meters (300 to 610 ft) and is conformably overlain by the Cook Mountain Formation.

The Cook Mountain Formation consists of four subdivisions: the Dodson, Milam's Marl, Saline Bayou, and Little Natchez members. The basal Dodson member consists of glauconitic sand, which often contains beds of almost pure glauconite, iron, or siderite lenses, and fossils. The overlying unit, called the Milam's Marl, is a unit of very fossiliferous clays and silts with interspersed fossiliferous siderite lenses. The lime content of the Milam's Marl increases southward. Overlying the Milam's Marl is the Saline Bayou member, which is composed of thin beds of clay and silt in the lower portion, and an almost pure silt bed in the upper portion. The Little Natchez member is the uppermost unit of the Cook Mountain and contains fine-grain, cross-bedded, slightly glauconitic sands with small amounts of silt and clay. There are occasional glauconite and ironstone ledges and fossil casts and molds. In some areas a unit has been identified above the Little Natchez member but has not been given a formal name. It is composed of a basal silt and clay overlain by a very thin, highly glauconitic sand with iron lenses, and fossils. Above this is a unit of alternating thin beds of silt and clay, with glauconite, siderite, fossils, and sand beds (Worley, 1962). It has been recognized in some parts of the study area, such as the northeast, but is not identified over the entire study area. The Cook Mountain is generally 18 to

91 meters (60 to 300 ft) thick and is conformably overlain by the Cockfield Formation.

The Cockfield includes both a lower marine and an upper nonmarine unit. The marine member consists of a cross-bedded, glauconitic, quartz sand, and the nonmarine unit is a nonglauconitic, quartz sand. These sandstones commonly contain leaf impressions, petrified wood, lignite beds, and fossil casts and molds. The thickness of the Cockfield in the study area ranges from 3 to 12 meters (10 to 40 ft).

Along stream valleys within the study area the formations of the Claiborne Stage/Group are unconformably overlain by Quaternary terraces and alluvium. The upper Eocene (Jackson), Oligocene, Miocene, and Pliocene units have either been eroded or were never deposited in the area.

9.2.2.6 Quaternary System - Quaternary terrace deposits cap the hills along most of the major stream valleys in the study area, and also the hills surrounding some of the salt domes. The terraces consist of upward fining fluvial sequences of gravel, sand, silt, and clay. Terrace development is related to Pleistocene glaciation, and to Red River erosion and deposition. Quaternary terraces in the study area range in thickness from 15 to 38 meters (50 to 125 ft).

Quaternary alluvium is also present along the flood plains of modern streams. The alluvium, from 3 to 8 meters (10 to 25 ft) thick, consists of interbedded sands, silts, and clays. The sands are generally yellowish brown to light brown and locally reddish brown to dark red. The grain size is fine to medium and sorting is poor to moderate. Pebbles are sometimes present. The sands are often mixed with clays which are red, brownish yellow, or very light gray. The percentage of silt in the alluvium varies from small amounts mixed in with the clays, to large concentrations in sandy and argillaceous siltstone beds, which contain traces of kaolinite, ironstone, and carbonaceous matter.

9.2.3 STRUCTURE: The regional structural features which affect the geology of the North Louisiana Study Area are the Sabine Uplift, Monroe-Sharkey Uplift, and the North Louisiana Syncline (Figure 9-6). The study area lies within the North Louisiana Syncline, which is flanked on the southwest by the Sabine Uplift and on the northeast by the Monroe-Sharkey Uplift. Gentle upwarping followed by a lower rate of subsidence of the two bordering structures, along with the contemporaneous and greater downwarping of the North Louisiana Syncline, suggests that a cause and effect relationship, perhaps involving isostatic adjustment, may be responsible for the development of these associated structural features (Murray, 1961).

The Sabine Uplift is a large, flat-topped domal structure situated partly in northwest Louisiana, northeast Texas, and southwest Arkansas (Figure 9-6). Pear-shaped in plan, this structure is 129 km (80 mi) long and 105 km (65 mi) wide. The longitudinal axis is oriented north-northwest to south-southeast. Well data indicate that primary graben faults may have defined the uplift as early as the Late Triassic and continued to affect

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deposition indirectly throughout the Cretaceous (Anderson, 1979). A regional gravity maximum and the presence of igneous rock in several wells over the uplift area suggest a plutonic igneous origin.

The Sabine Uplift is expressed at the surface by an inlier of Wilcox beds encircled by Claibornian deposits on the flanks. Northeast of the Sabine Uplift is the D'Arbonne Platform, a broad monocline which dips gently to the northeast (Durham, 1964). The D'Arbonne Platform and the Sabine Uplift are the primary surface structural features nearest the study area.

The Monroe-Sharkey Uplift is also a large, relatively flat-topped, domal feature. It is similar to the Sabine Uplift in structural development and sedimentary history, but is limited to the subsurface. This structure is located east of the study area, partly in northeast Louisiana, southeast Arkansas, and western Mississippi (Figure 9-6).

The North Louisiana Syncline (Figures 9-6 and 9-7) is a triangular-shaped feature which plunges to the southeast along a northwest-southeast trending axis. The growth of this structure is reflected by every subsurface stratigraphic unit for which adequate information is available; however, the structure is not expressed at the surface. The North Louisiana Syncline contains the North Louisiana Salt Basin, which is the central one of the three Interior Salt Basins situated in the the northern Gulf Coastal Region (Figure 9-6). Nineteen salt domes are known within the basin. Echols (1965) subdivided the North Louisiana Salt Basin into the Minden Basin on the north and the Winnfield Basin on the south, separated by the east-west trending Lake Bistineau Structural Bridge (Figure 9-7).

Regional structural contours on the base of the Ferry Lake Formation reveal approximately 914 and 1,372 meters (3,000 and 4,500 ft) of structural relief between the axis of the syncline and the apices of the Sabine and Monroe-Sharkey Uplifts, respectively (Murray, 1961). Within the study area, contours on the base of the Ferry Lake indicate approximately 914 meters (3,000 ft) of structural relief between the axis of the Minden Basin and the apex of the Lake Bistineau Structural Bridge (Figure 9-9).

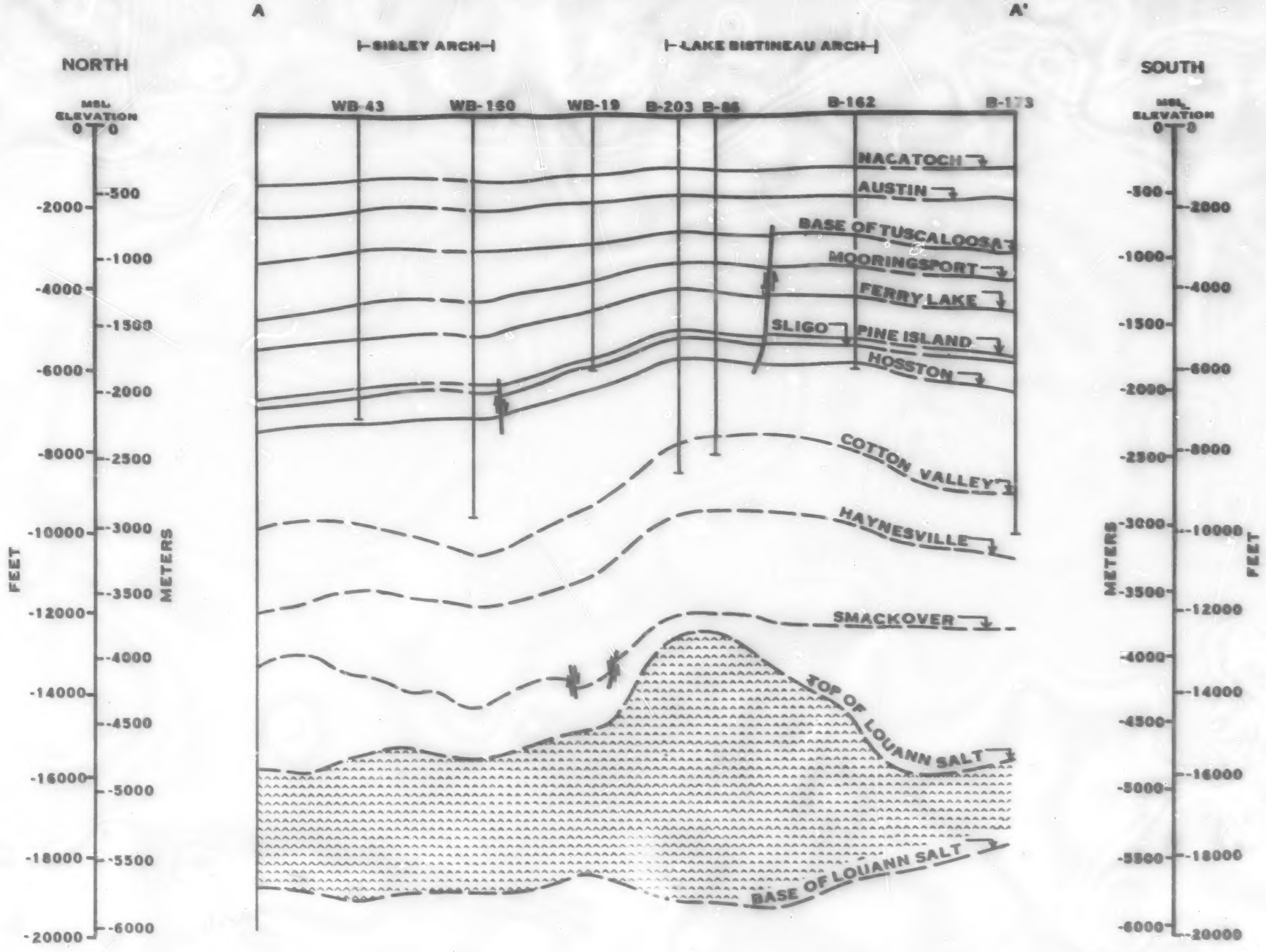
The development of numerous salt domes and other salt-controlled structures complicated the initial simplicity of the North Louisiana Syncline. For example, positive anomalies, such as the Lake Bistineau Structural Bridge, and the bordering negative features (Minden and Winnfield Basins) are so prominent that they disrupt the structural character of the syncline. These relationships suggest that the syncline was a "low" during the Early-to-Middle Jurassic deposition of the Louann Salt (Murray, 1961).

9.2.3.1 Primary Structural Features: The Minden and Winnfield Basins, together with the Lake Bistineau Structural Bridge, represent the primary structural features of the study area. (The development of the Minden and Winnfield Basins in relation to salt deposition and subsequent movement is described in Section 9.2.3.2.)

9.2.3.1.1 Lake Bistineau Structural Bridge - The Lake Bistineau Structural Bridge (Figure 9-7) is a broad, complex, saddle-like feature, which trends east-west between the Sabine and Monroe-Sharkey Uplifts. The bridge originated in the Late Triassic and was probably structurally expressed throughout the Jurassic and Cretaceous (Anderson, 1979). The movement of salt undoubtedly altered the structure of the bridge during the latter period.

The Lake Bistineau Structural Bridge was a major influence on depositional patterns during most of the Mesozoic Era. For example, massive Dorcheat sands of the Cotton Valley Group were deposited along its crest during the Late Jurassic (Figure 9-10), and the Washita, Fredericksburg, and uppermost Trinity sediments were beveled off of the bridge, indicating structural expression during late Comanchean emergence. (See Table 9-1 for the stratigraphic column of the study area.) The similarity between the development of the Upper Jurassic Dorcheat and the Gulfian Brownstown Formations suggests that the Lake Bistineau Structural Bridge was present as a positive, controlling element well into the Late Cretaceous.

On the basis of gravity and seismic data (Figure 9-10), the Lake Bistineau Structural Bridge appears to coincide in position with a salt ridge. However, Anderson (1979) suggests that the structure is a Triassic horst, and the Minden and Winnfield Basins are adjoining grabens. Although there is evidence to support Anderson's interpretation, recent seismic and gravity data indicate the bridge to be a salt structure.



3 0 3 MILES
4 2 0 4 KILOMETERS
VERTICAL EXAGGERATION 5X.

LOCATION OF SECTION ON FIGURE 9-3

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1

LEGEND

— SEISMIC REFLECTOR (DASHED WHERE INFERRED)

▨ SALT

/// NORMAL FAULT - ARROWS SHOW DIRECTION OF RELATIVE MOVEMENT

PREPARED		DATE	12/18/80
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REVISED		DATE	
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NORTH LOUISIANA STUDY AREA
SEISMIC SECTION A - A'

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FIGURE 9-10

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Echols (1965) divided the bridge into a western stable area and an eastern deformed area. The stable area coincides with the boundaries of the Lake Bistineau Arch (Figure 9-7) located in the western portion of the study area. The deformed bridge, which includes the Sailes Arch, the West Bryceland High, the Bear Creek Arch, and the Driscoll Arch, represents the remainder of the Lake Bistineau Structural Bridge. The stable bridge was less influenced by salt migration than its deformed counterpart.

9.2.3.1.2 Minden Basin - The Minden Basin is a sinuous, synclinal feature, bounded by the Sabine Uplift to the west and northwest, the Ivan Desmoanticline to the north, the Monroe-Sharkey Uplift to the east, and the Lake Bistineau Structural Bridge to the south (Figures 9-6 and 9-7). Five shallow-piercement domes -- Vacherie, Minden, Bistineau, Arcadia, and Gibsland (see Section 9.2.3.4) -- are situated along the basinal axis. The basin probably formed during the Late Triassic as the Central Eagle Mills Graben between the State-Line and Lake Bistineau Horsts (Anderson, 1979).

9.2.3.1.3 Winnfield Basin - The Winnfield Basin is an irregular depression, bounded on the northwest by the Lake Bistineau Structural Bridge, on the west and southwest by the Sabine Uplift, on the south by the Toledo Bend Flexure, and on the northeast by the Monroe-Sharkey Uplift (Figures 9-6 and 9-7). This basin is less distinctly defined than the Minden Basin and, being more open to the south, has less closure. There are 14 piercement domes within the basin, five of which lie within the study area -- Rayburn's, Kings, Chestnut, Prothro, and Prices Domes. The basin probably formed during the Late Triassic as the Southern Eagle Mills Graben between the Lake Bistineau Horst and the Toledo Bend Flexure (Anderson, 1979).

The various domes and associated subbasins within the Minden and Winnfield Basins are discussed in Section 9.2.3.4.

9.2.3.2 **Salt Movement:** The structural features within the study area developed further in response to the movement of the Louann Salt, which was deposited in beds 457 to 914 meters (1,500 to 3,000 ft) thick during the Early to Middle Jurassic. A combination of physical factors, such as uneven sediment loading and buoyant forces due to differential densities of the salt and the overlying sediments, initiated salt flowage soon after the beginning of sedimentation.

Numerous models for salt dome development have been introduced. Kupfer's (1976) model consists of the following four stages of development:

(1) Horizontal movement, with local concentrations forming pillows

(2) Active vertical movement, with domal salt piercing overlying strata, or the overlying strata engulfing the salt domes, and formation of rim synclines

(3) Vertical movement, detached or stove-pipe stage

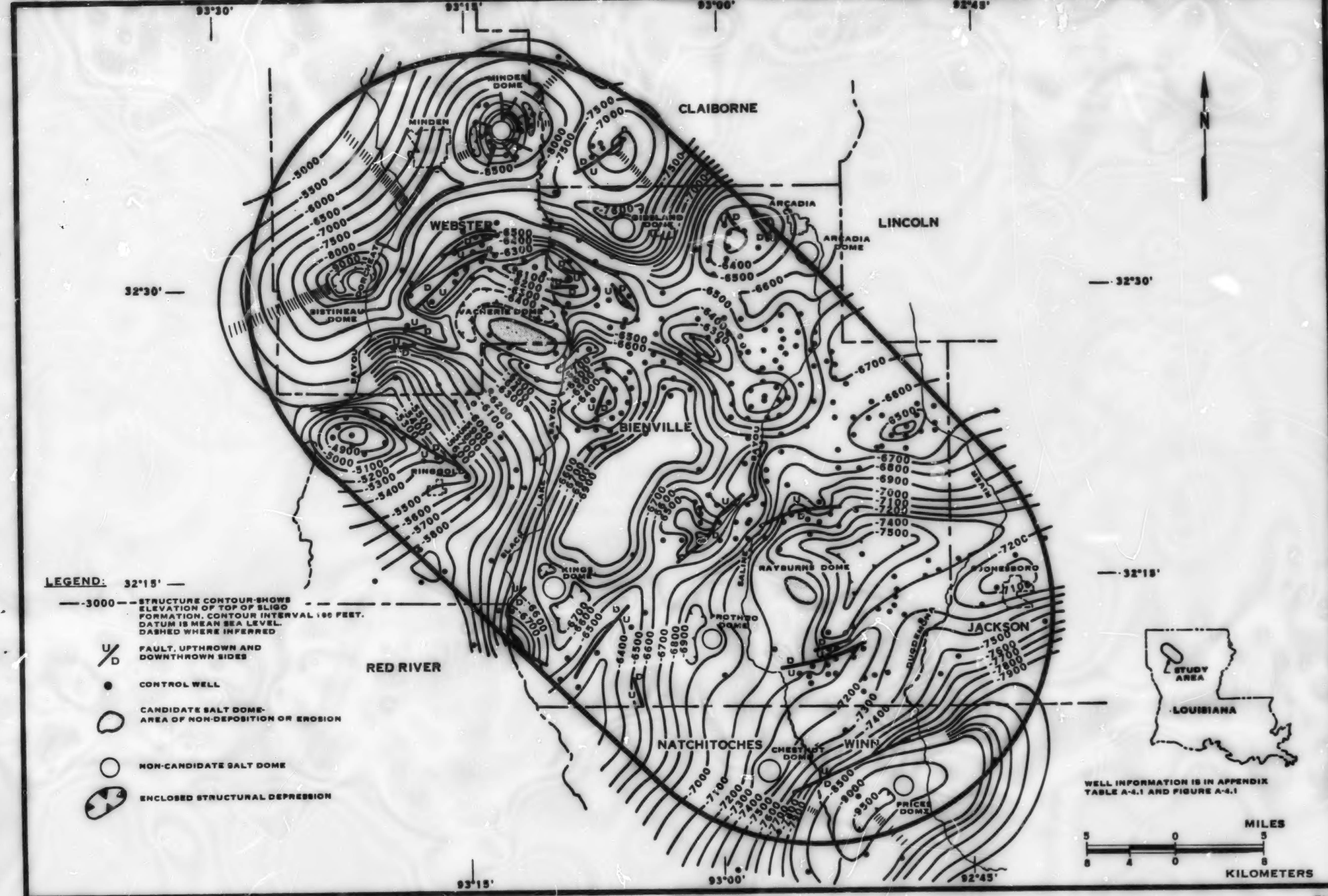
(4) Finale, with cessation of movement.

Trusheim (1960), Kehle (1978), and Loocke (1978) have also proposed models for salt dome development. Like Kupfer's model, these models propose an initial horizontal stage of movement, followed by vertical (diapiric) movement or engulfing by down-building, and a subsequent post-diapiric stage. A detailed discussion of all three models is presented in Section 2.2 of Volume I.

The salt-movement history of the Minden Basin contrasts with its Winnfield counterpart in several ways. There is a less regular distribution of salt domes within the Winnfield Basin, which suggests that the domes developed from a complex network of vermiform pillows rather than one central pillow, as in the Minden Basin. Also, although seismic information is limited, it appears that the thicknesses of the overburden and of the mother salt are greater and more variable in the Winnfield Basin. The domes in the Minden Basin generally have more consistent and shallower depths to caprock, and are more evenly spaced than those in the Winnfield Basin. The tops of the domes in the Winnfield Basin occur both much shallower and much deeper than in the Minden Basin. Such differences may indicate that a more mature stage of salt tectonism was reached by the time of stabilization in the Winnfield Basin than in the Minden Basin (Anderson, 1979).

9.2.3.2.1 Secondary Structural Features - Secondary structural features within the study area, consisting of anticlinal arches, ridges, highs, and associated synclines (Figure 9-7), developed in response to salt movement. Structurally, the synclines are probably equally complex but, being deeper and of negligible interest for oil and gas, they lack significant exploration data.

9.2.3.2.1.1 Darley High: The Darley High is a domal feature located approximately 10 km (6 mi) north of Gibsland Dome. Structural contour maps of the top of the Sligo (Figure 9-11) and base of the Ferry Lake Formations (Figure 9-9), and seismic data (Figure 9-12) indicate this structure, which developed in response to the growth of Gibsland Dome, was a residual high during the Early Cretaceous deposition of the rocks of the Hosston Formation upward to the base of the Tuscaloosa. The Cotton Valley Group thickens over the high, suggesting that lateral salt migration occurred during this time, coincident with the early growth stage of Gibsland Dome. The feature has 427 meters (1,400 ft) of structural relief on the Sligo horizon (Figure 9-11), and the lower Trinity (Rodessa, James, and Pine Island Formations) isopach contour map (Figure 9-13) shows a thinning over the structure, indicative of the significant vertical growth of the Gibsland salt stock during the time of deposition of this part of the section. Development diminished during the Late Cretaceous, reflected in the minimal relief indicated on the base of the Annona structural contour map (Figure 9-14). There was little or no development during the Tertiary Period (Figures 9-15, 9-16, 9-17 and 9-18). (Locations of geologic section lines are shown in Figure 9-3. Information on well logs used can be found in Appendix Table A-4.1.)



NORTH LOUISIANA STUDY AREA
STRUCTURAL CONTOUR MAP
TOP OF SLIGO FORMATION

FIGURE 9-11

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
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REVISED [illegible] DATE [illegible]
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FIGURE 9-11

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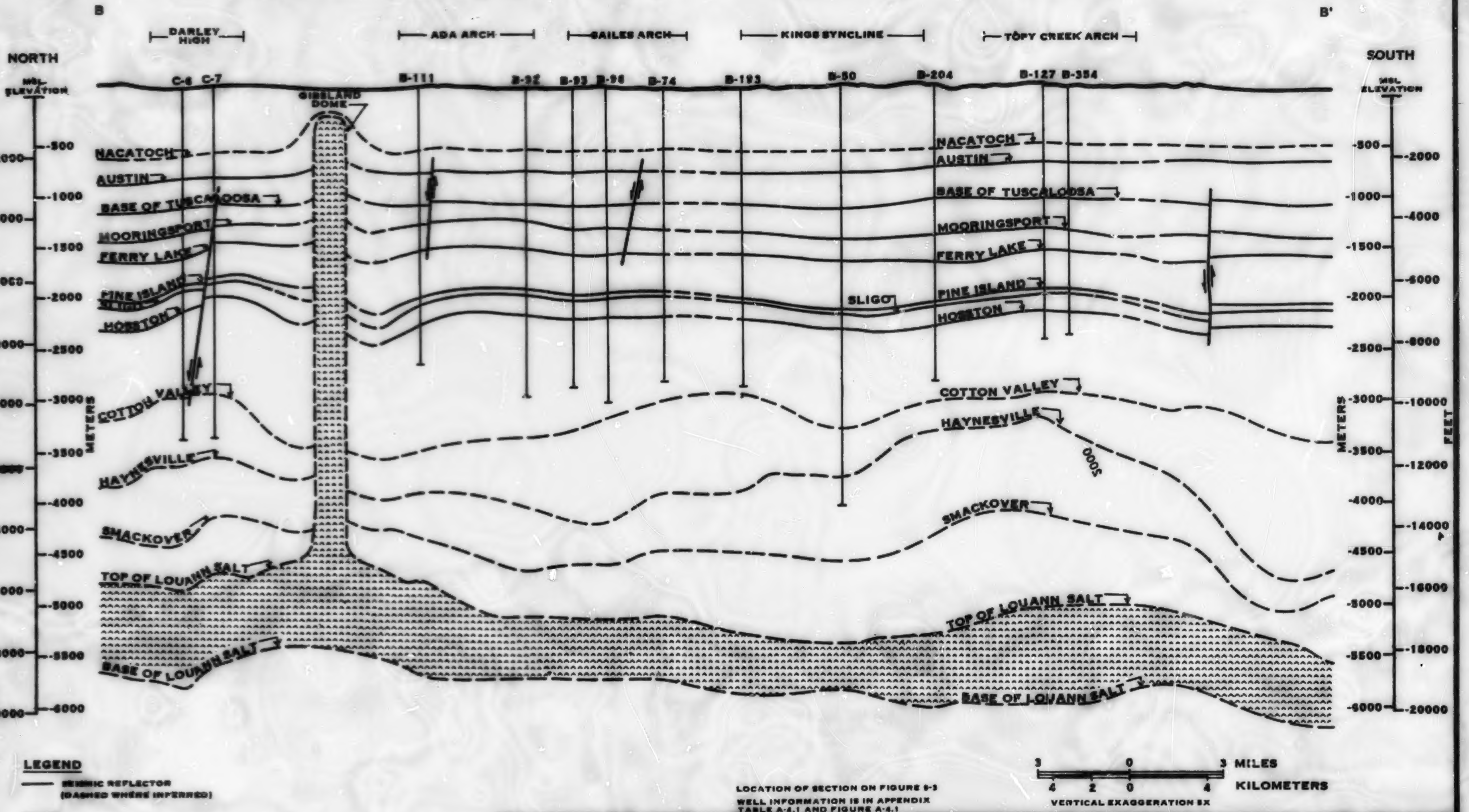

LEGEND

SEISMIC REFLECTOR (DASHED WHERE INFERRED)

▨ SALT

NORMAL FAULT - ARROWS SHOW DIRECTION OF RELATIVE MOVEMENT

LOCATION OF SECTION ON FIGURE 9-3

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1

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REVISED	DATE
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NORTH LOUISIANA STUDY AREA

SEISMIC SECTION B - B'

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FIGURE 9-12

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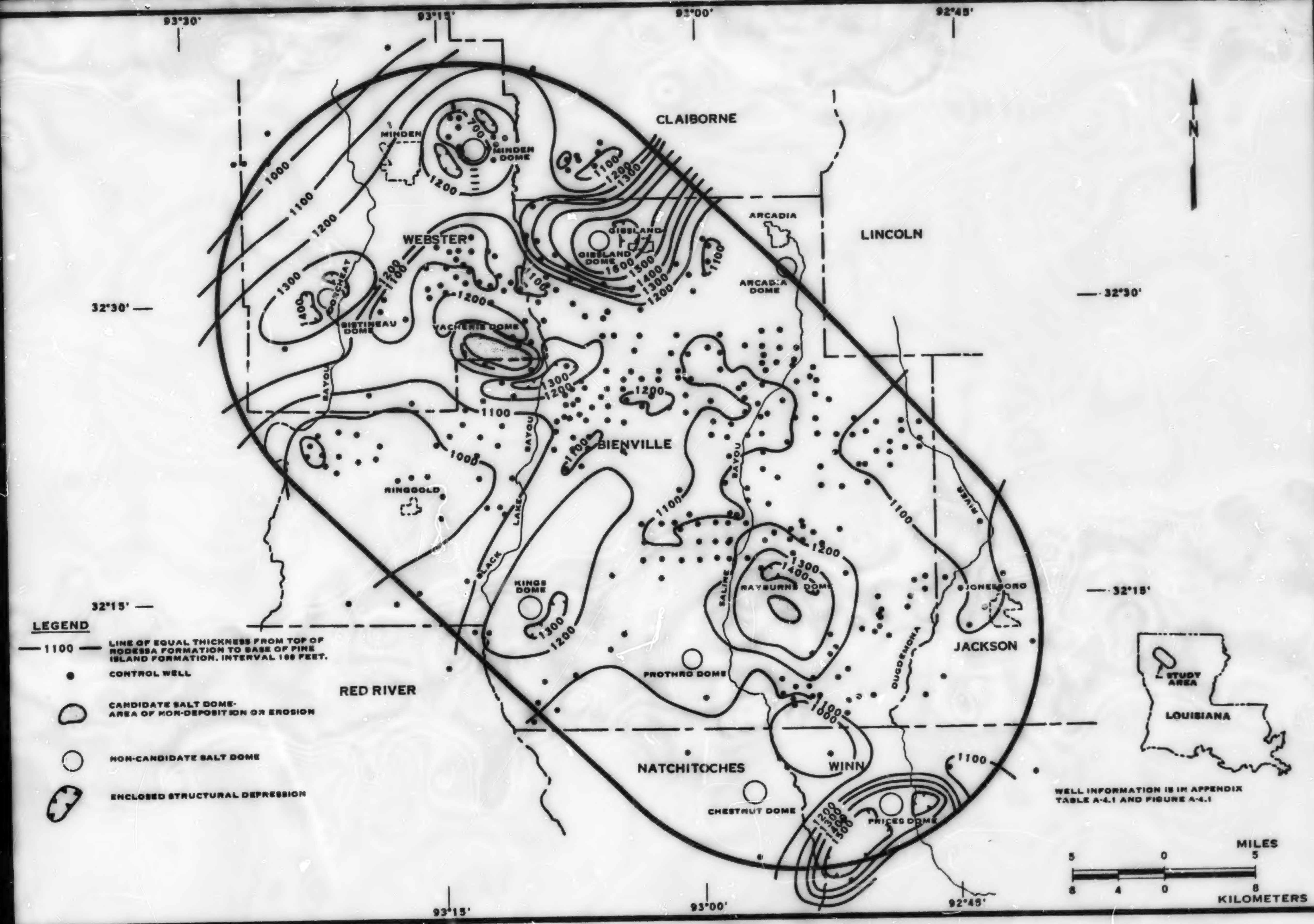

NORTH LOUISIANA STUDY AREA

ISOPACHOUS CONTOUR MAP
OF RODESSA, JAMES, AND
PINE ISLAND FORMATIONS

JOB NO. MV9600

FIGURE 9-13

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 9-13

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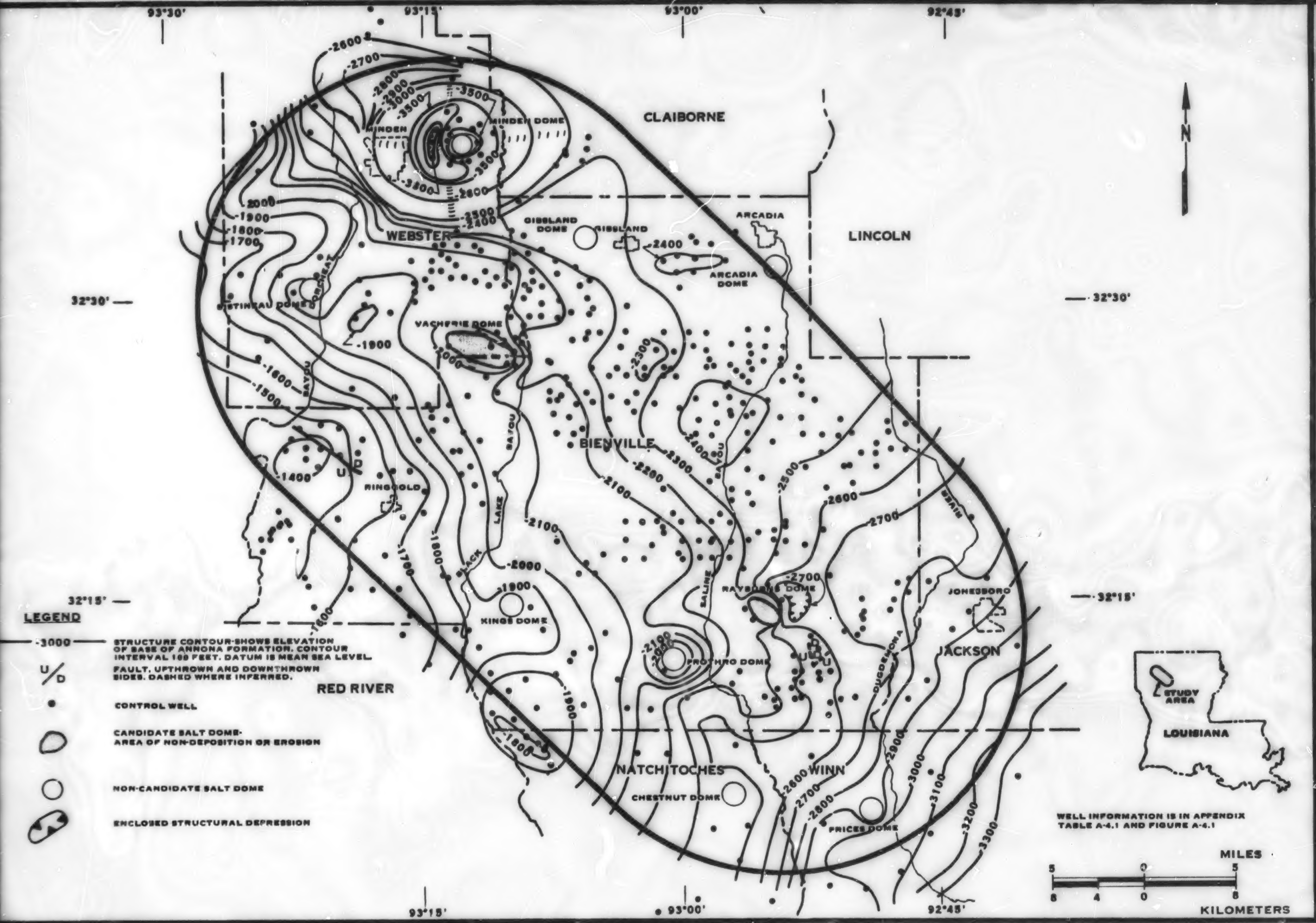

LEGEND

-3000 STRUCTURE CONTOUR-SHOWS ELEVATION OF BASE OF ANNONA FORMATION. CONTOUR INTERVAL 100 FEET. DATUM IS MEAN SEA LEVEL.

U/D FAULT, UPTHROWN AND DOWNTHROWN SIDES. DASHED WHERE INFERRED.

● CONTROL WELL

CANDIDATE SALT DOME-AREA OF NON-DEPOSITION OR EROSION

○ NON-CANDIDATE SALT DOME

ENCLOSED STRUCTURAL DEPRESSION

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1

NORTH LOUISIANA STUDY AREA

STRUCTURAL CONTOUR MAP
BASE OF THE ANNONA FORMATION

JOB NO. MV9600

FIGURE 9-14

NATIONAL WASTE TERMINAL
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GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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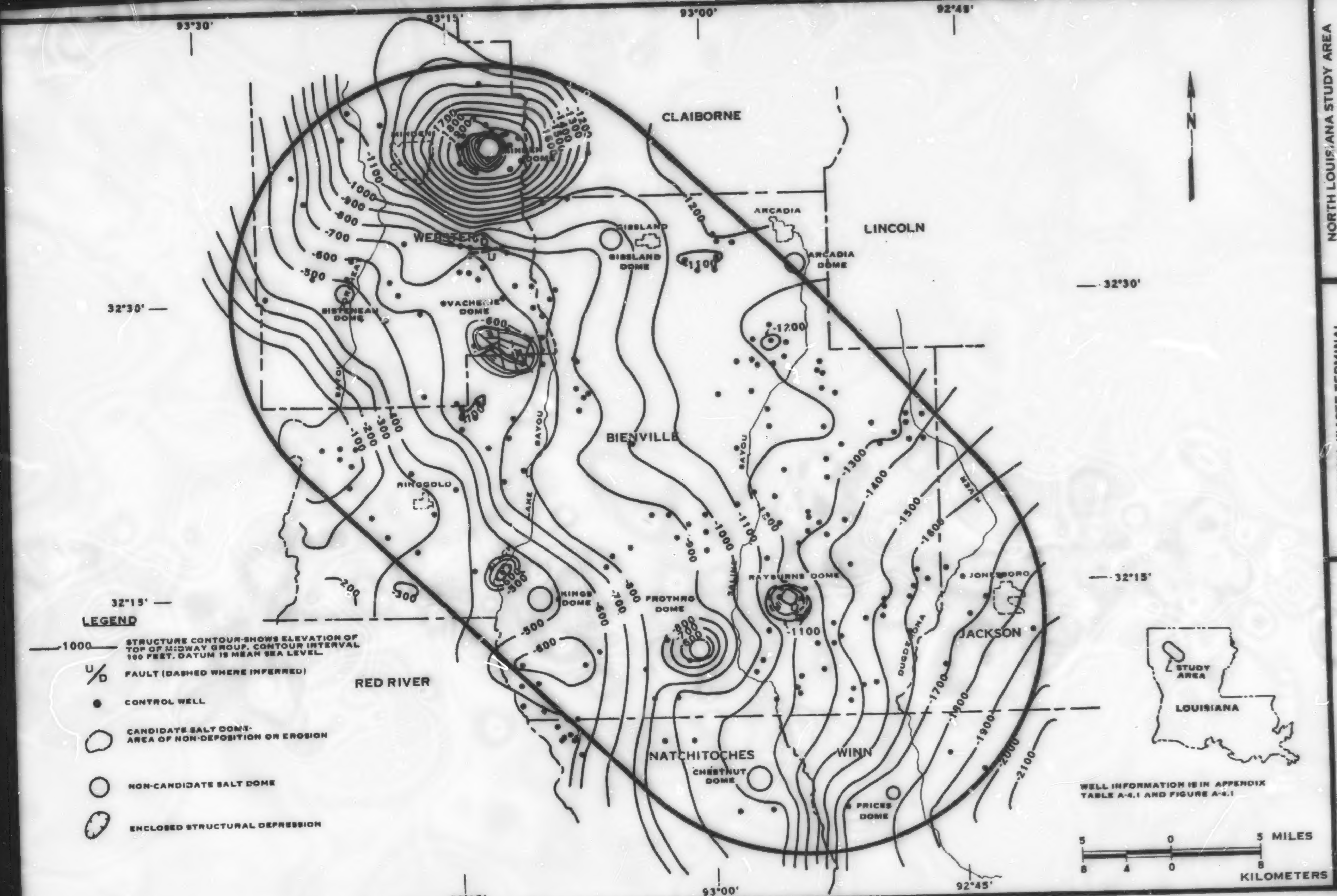
FIGURE 9-14 [redacted]



LEGEND

-1000 STRUCTURE CONTOUR-SHOWS ELEVATION OF TOP OF MIDWAY GROUP. CONTOUR INTERVAL 100 FEET. DATUM IS MEAN SEA LEVEL.

U/D FAULT (DASHED WHERE INFERRED)

● CONTROL WELL

CANDIDATE SALT DOME-AREA OF NON-DEPOSITION OR EROSION

○ NON-CANDIDATE SALT DOME

ENCLOSED STRUCTURAL DEPRESSION

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1

NORTH LOUISIANA STUDY AREA

STRUCTURAL CONTOUR MAP
TOP OF MIDWAY GROUP

JOB NO. MV9600

FIGURE 9-15

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

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REVISED [illegible] DATE [illegible]
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FIGURE 9-15

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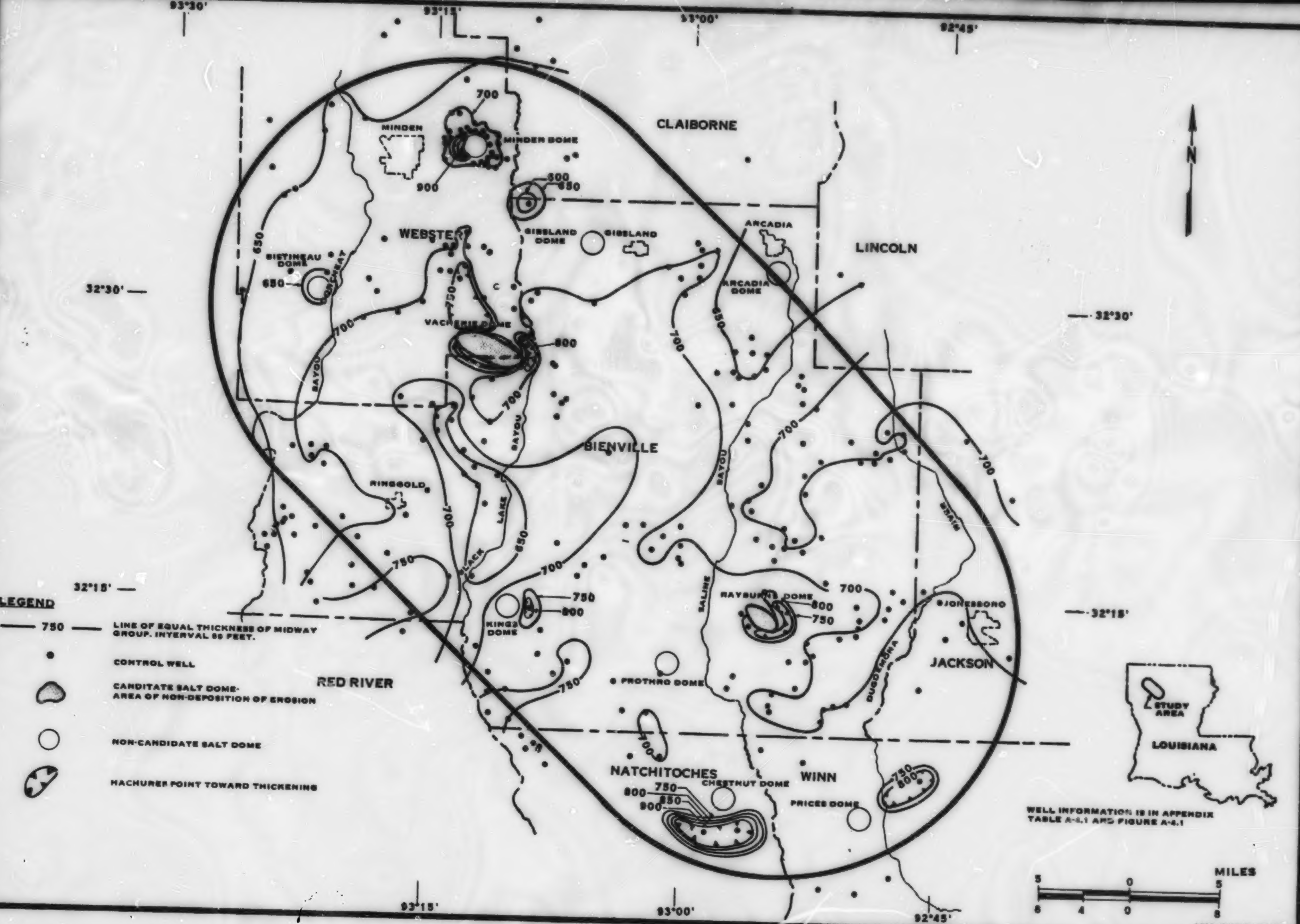

NORTH LOUISIANA STUDY AREA

ISOPACHOUS CONTOUR MAP OF MIDWAY GROUP

JOB NO. MV9600

FIGURE 9-16

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

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FIGURE 9-16

58

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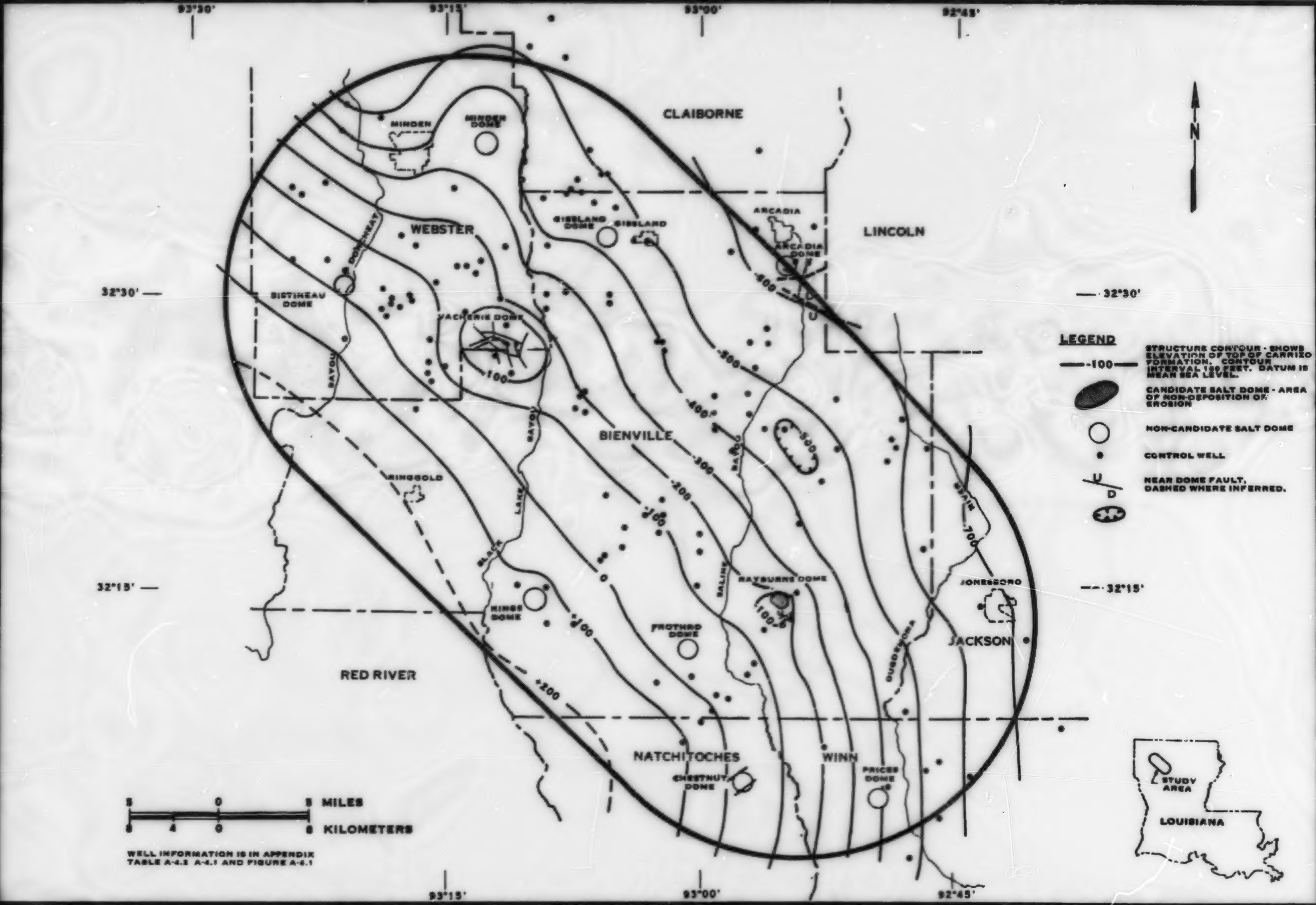

NORTH LOUISIANA STUDY AREA
STRUCTURAL CONTOUR MAP
TOP OF CARRIZO FORMATION

JOB NO. MV9600

FIGURE 9-17

NATIONAL WASTE TERMINAL
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GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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REVISED ____ DATE [illegible]
REVISED ____ DATE 9/28/81
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FIGURE 9-17

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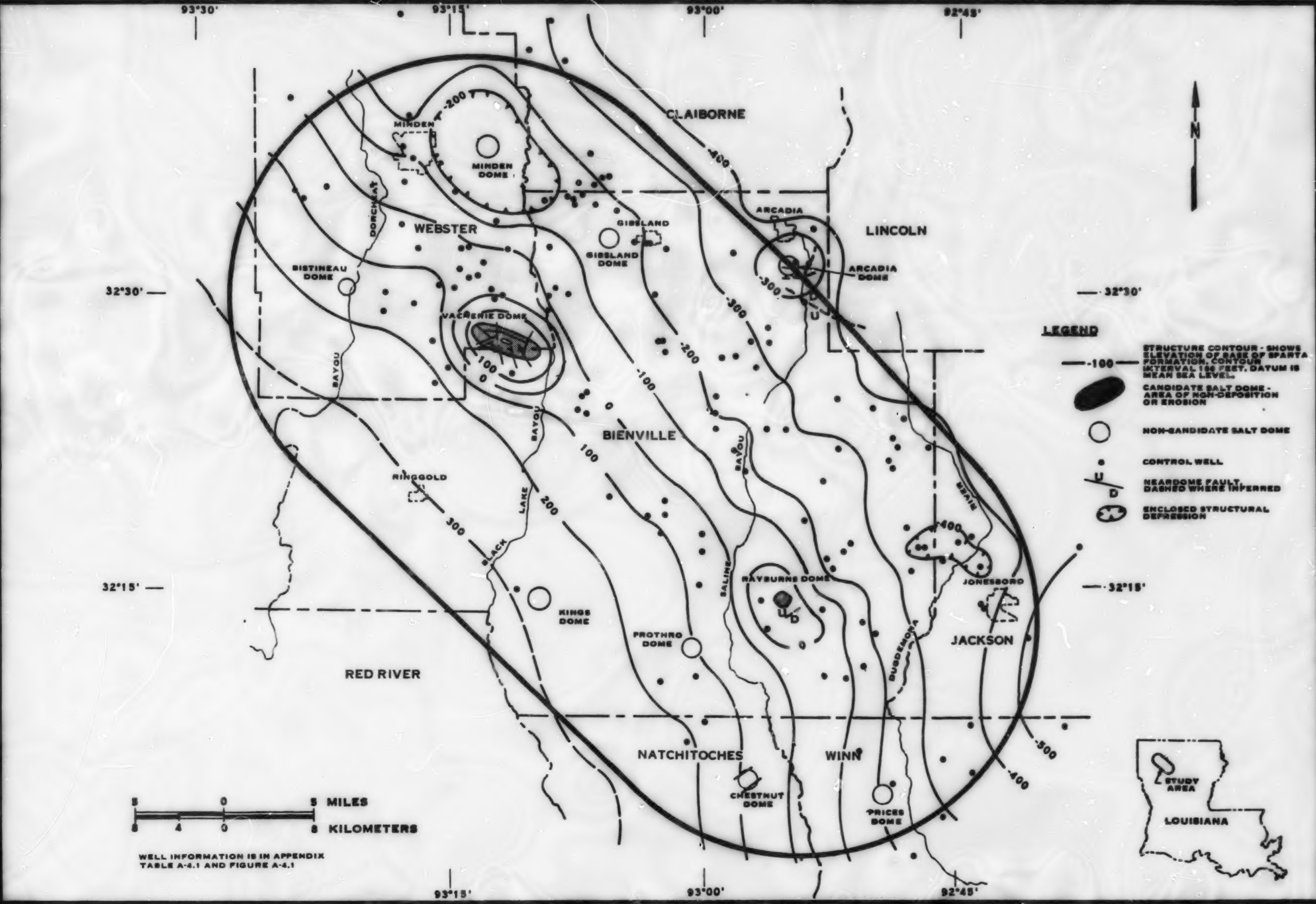

NORTH LOUISIANA STUDY AREA
STRUCTURAL CONTOUR MAP
BASE OF SPARTA FORMATION

JOB NO. MV9600

FIGURE 9-18

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 9-18

60

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9.2.3.2.1.2 Lake Bistineau Arch: The eastern portion of the Lake Bistineau Arch lies within the study area. The 1,554-meter (5,100-ft) contour on the base of the Ferry Lake structural contour map (Figure 9-9) is arbitrarily designated the boundary between the arch and the adjoining Vacherie and Bistineau Subbasins (Crowe, 1975). There is 457 meters (1,500 ft) of structural relief on the base of the Ferry Lake between the top of the arch and the lowest point in Vacherie Subbasin, indicating the significant development (relative to the subbasin) which occurred during the Early Cretaceous. The structure continued to develop at a lesser rate through the Tertiary as shown by the 198 and 152 meters (650 and 500 ft) of structural relief on the base of the Annona Formation (Figure 9-14) and the top of the Midway Group (Figure 9-15), respectively. Development had ceased by the time of deposition of the Carrizo Formation (Figure 9-17). Seismic and gravity data suggest that the Lake Bistineau Arch is underlain by a salt ridge (Figure 9-10).

The Lake Bistineau Arch, which exhibits the greatest structural relief of all the highs within the study area, is the stable part of the Lake Bistineau Structural Bridge.

9.2.3.2.1.3 Ada, Sibley, and Sailes Arches: The Ada, Sibley, and Sailes Arches have similar evolutionary histories. The Sibley and Ada Arches are elongated in the Lower Cretaceous units and become almost indiscernible in the overlying Upper Cretaceous units (Figure 9-14). The axis of the Minden Basin isolates the Sibley and Ada Arches from the rest of the Lake Bistineau

Structural Bridge (Figure 9-7). The Sibley-Ada feature was a residual high apparently isolated by salt withdrawal during the Late Jurassic. The amount of structural relief, as well as the average dip of the beds on the flanks of the arches, decreases upward in the section. Structural relief is most pronounced on the top of the Sligo horizon (Figure 9-11) and on the base of the Ferry Lake (Figure 9-9). The differences in structural relief and dip between the base of the Ferry Lake and top of the Sligo horizons indicate that significant development of these anticlinal structures occurred before deposition of the Rodessa Formation. Seismic sections A-A' and B-B' (Figures 9-10 and 9-12) illustrate that the unconformity at the base of the Gulfian marked the end of the major structural development of these features.

Estimates of the time of subsidence of the subbasins can be established by comparing thicknesses of formations on the arches with corresponding thicknesses in the subbasins. Units deposited during a period of active downwarping would have significantly greater thicknesses in the basin than on the bordering anticline (Crowe, 1975). Sligo beds on the Ada Arch are significantly thinner than the corresponding units in the Gibsland Subbasin to the north (Figure 9-12) and about the same as in the Vacherie Subbasin to the south. The asymmetry of the amount of thickening strongly suggests that the structural relief exhibited at this time is due to subsidence of the Gibsland Subbasin, rather than to uplift of the Ada Arch.

By the time of lower Trinity deposition, the Ada, Sibley, and Sailes Arches show thinning over their crests, suggesting continued development of the subbasins. However, by the time of Austin-Eagle Ford deposition (Figure 9-19), the amount of thinning decreases over the Ada and Sailes Arches, suggesting a decrease in the development of the surrounding salt domes.

In contrast, Jurassic units studied are thicker over the arches than in the subbasins (Figure 9-12). Seismic data indicate that the Cotton Valley beds are thickest near the present crest of the arches and gradually thin toward the subbasins.

The trends of thickening and thinning over the three arches indicate that they were residual highs which resulted from the subsidence of surrounding sediments as the Louann Salt migrated during the growth of associated domes. Major development of these structures occurred during the deposition of the lower Trinity, which corresponds to the time of greatest development of Vacherie, Bistineau, and Gibsland Domes.

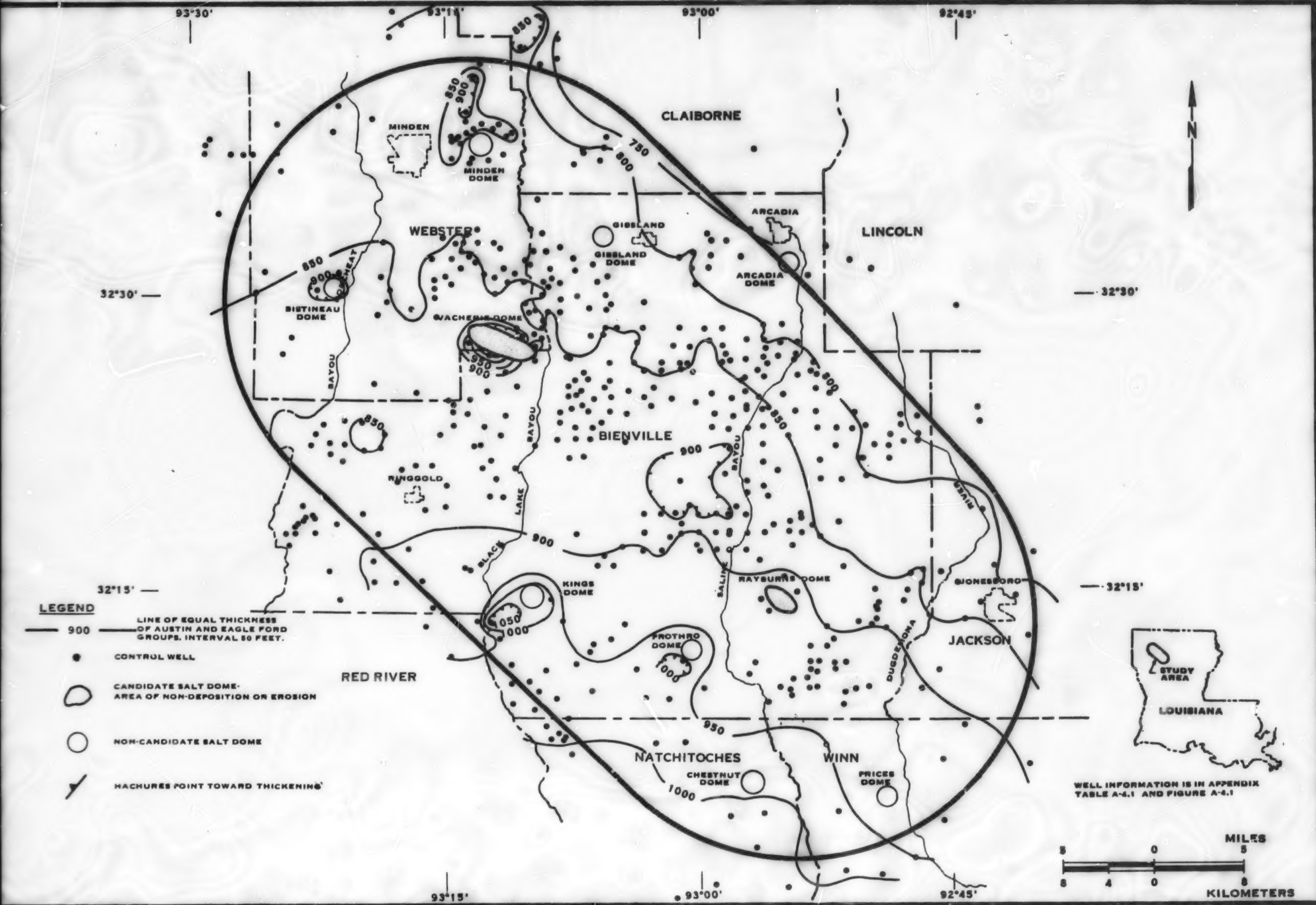
9.2.3.2.1.4 West Bryceland High, Bear Creek and Driscoll Arches: These three anticlinal highs also have similar evolutionary histories. Sediments over the West Bryceland High and the Bear Creek and Driscoll Arches begin to show thinning during lower Trinity deposition (Figure 9-13). Major structural development had decreased by the beginning of the Late Cretaceous and had ceased by the end of that period.

These three elliptical structures have longitudinal axes oriented northwest-southeast. Structural relief on the top of the Sligo horizon averages about 76 meters (250 ft) over the Bear Creek and Driscoll Arches, and 107 meters (350 ft) over the West Bryceland High (Figures 9-7 and 9-11). West Bryceland High and Bear Creek Arch continued to show positive tendencies, although decreasingly during the Late Cretaceous, but the Driscoll Arch had ceased to remain structurally high by the end of Annona deposition (Figures 9-7 and 9-14).

The West Bryceland High and the Bear Creek and Driscoll Arches comprise much of the deformed region of the Lake Bistineau Structural Bridge (Figure 9-7).

9.2.3.2.1.5 Arcadia Arch: The Arcadia Arch is a residual anticlinal high which developed as a result of salt withdrawal into the Arcadia Subbasin to the southeast. An isopach contour map of the lower Trinity (Figure 9-13) shows that relative contemporaneous thinning on the Arch, compared with the thickened adjacent subbasin, continued at a decreasing rate through the Early Cretaceous (Figure 9-19).

Structural relief on the top of the Sligo is approximately 305 meters (1,000 ft) from the apex of the arch to the deepest part of the Arcadia Subbasin. This amount of relief is maintained throughout the Lower Cretaceous, but decreases to less than 61 meters (200 ft) on Upper Cretaceous horizons. The Midway structural contour map (Figure 9-15) indicates that there was no development relative to the subsiding subbasin during the early Tertiary. Minor rejuvenation occurred prior to the deposition of the Sparta Formation (Figure 9-18).



NORTH LOUISIANA STUDY AREA

ISOPACHOUS CONTOUR MAP OF
AUSTIN AND EAGLE FORD GROUPS

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FIGURE 9-19

NATIONAL WASTE TERMINAL
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GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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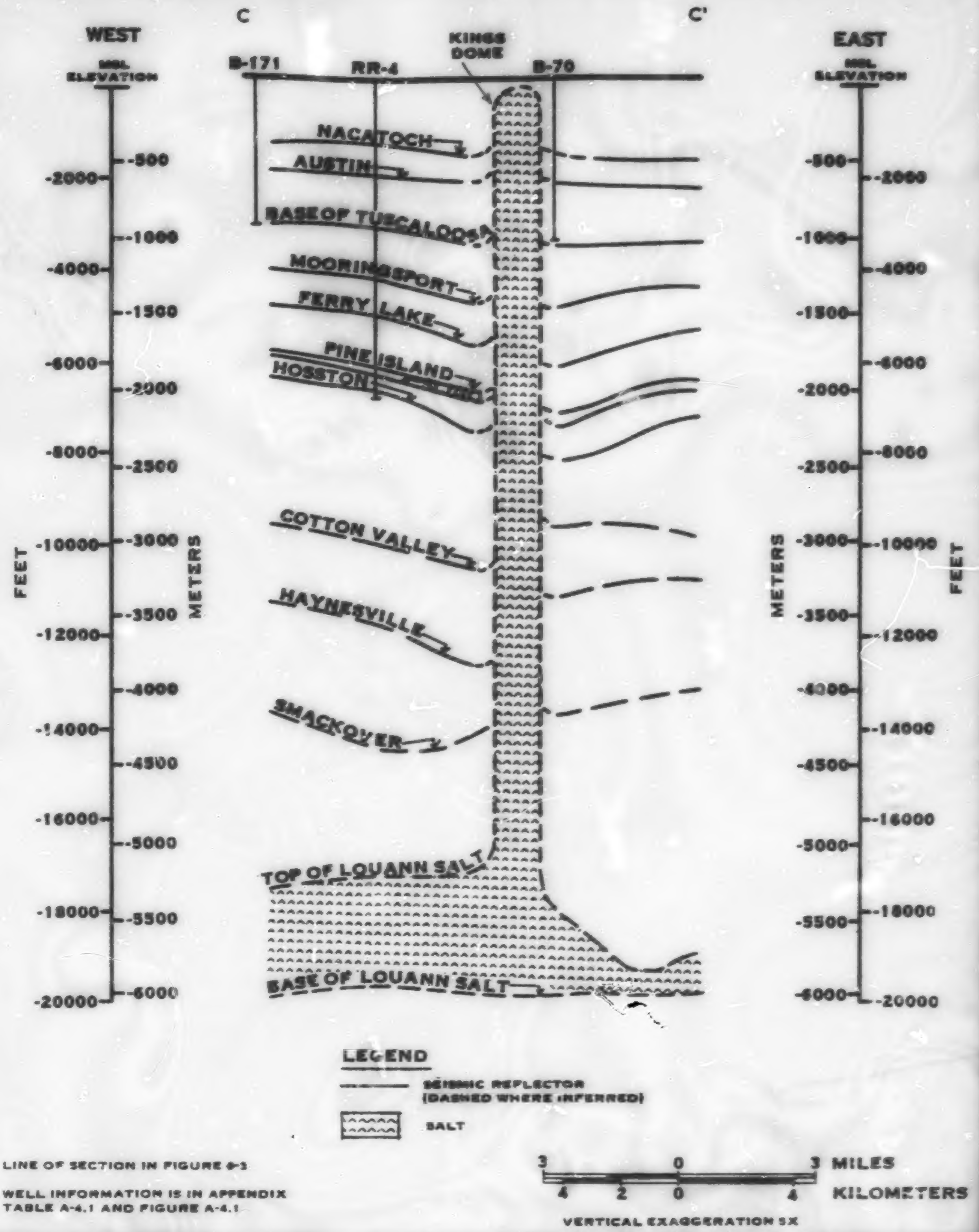
FIGURE 9-19

9.2.3.2.1.6 Kings Syncline: Kings Syncline is a salt withdrawal basin located between the Sailes Arch and the Lucky Arch (Figure 9-7). It is an extensive 16-km (10-mi) long synclinal feature with a northeast-southwest axis. This basin was the source area for much of the salt that migrated to form the boundary features and the Kings Dome stock (Crowe, 1975). Seismic data indicates rim syncline development near Kings Dome during Late Jurassic through Early Cretaceous time (Figure 9-20). Limited well control prevents a detailed interpretation of the structural development of this basin.

9.2.3.2.1.7 Topy Creek Arch: The Topy Creek Arch was a well defined positive feature during the Early Cretaceous (Figure 9-11). The structural contour map drawn on the base of the Ferry Lake (Figure 9-9) shows the arch as a relatively high feature with over 61 meters (200 ft) of closure. However, during Mooringsport deposition, the arch became a broad, arcuate feature, semicircular and dome-like, with minor thinning relative to the adjacent subbasin. This configuration is probably due to post-Rodessa deformation (Reese, 1977). This development pattern continued until the end of the Early Cretaceous. Structural development during the Late Cretaceous was confined to the western end of the arch (Figure 9-14). During the early Tertiary, the Topy Creek feature was developed to a minor extent (Figures 9-7 and 9-15). Development had ceased prior to deposition of the Cane River Formation (Figures 9-17 and 9-18).



LINE OF SECTION IN FIGURE 9-3

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1

PREPARED DATE
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REVISED DATE
APPROVED GHE DATE 12/23/80
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MARIETTA GEORGIA

NORTH LOUISIANA STUDY ARE
SEISMIC SECTION C - C'
JOB NO. MV9600
FIGURE 9-

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9.2.3.2.1.8 Lucky Arch: Maximum structural development of the Lucky Arch occurred during the deposition of the lower Trinity. The end of Rodessa deposition marked the beginning of the degeneration of the Lucky Arch as a prominent positive feature (Figure 9-9). The Ferry Lake Formation shows generally uniform thickness over the structure, and there is minor thinning of the Mooringsport member of the Rusk Formation over the arch (Figure 9-21). By the end of the Early Cretaceous the Lucky Arch had ceased to be a prominent structural high. Maximum relief reached 91 meters (300 ft) on the top of the Sligo horizon (Figure 9-11).

Renewed development occurred during the Late Cretaceous, though minor compared to that of prior stages, and was concentrated in the northwest portion of the arch. This development occurred primarily during upper Taylor and Navarro deposition (Reese, 1977).

9.2.3.2.1.9 Jonesboro Ridge: The structural nature of the Jonesboro Ridge is similar to that of the Topy Creek and Lucky Arches. It was a high during the Early Cretaceous, but exhibited only a minor amount of relief (15 meters (50 ft)). During the Late Cretaceous, there was minimal thinning as the Jonesboro Ridge became essentially stable relative to the subbasins (Figure 9-22).

9.2.3.2.1.10 Danville High: The Danville High is an anticlinal feature that was well-differentiated during the Early Cretaceous but had very little expression during the Late Cretaceous (Figure

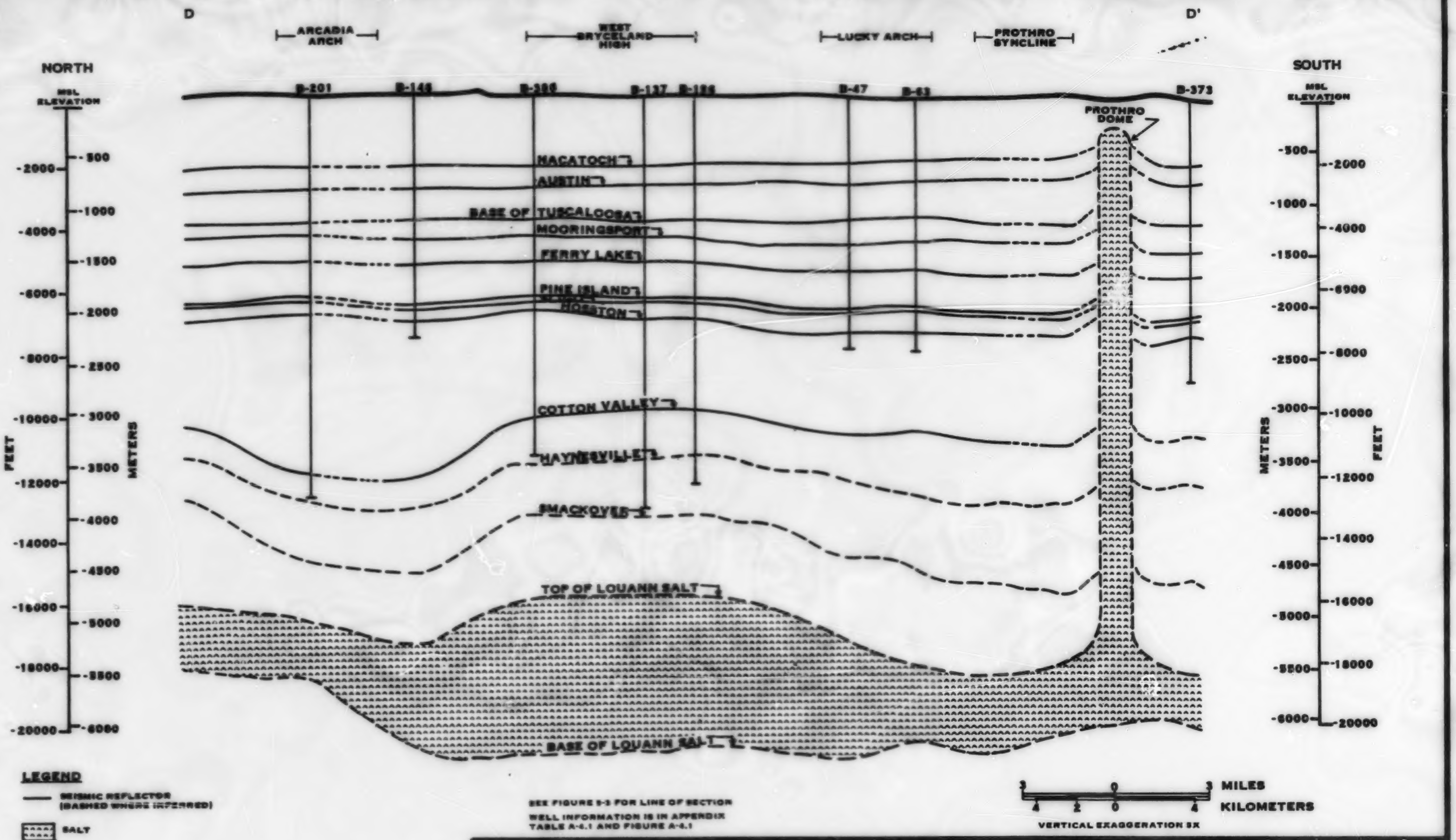
[redacted]

9-23). Maximum relief of 732 meters (2,400 ft) from the deepest known areas of the Prices Syncline to the crest of the Arch is shown on the Sligo structural contour map (Figure 9-11). Local relief is reduced to 701 meters (2,300 ft) on the base of the Ferry Lake (Figure 9-9). As with most anticlinal features within the study area, relative development of the Danville High was not apparent after deposition of the Midway (Figures 9-15, 9-17, and 9-18).

9.2.3.2.1.11 Prothro Syncline: The general history of structural growth of the Prothro Syncline through Cretaceous and early Tertiary time is believed to be similar to that of the Kings Syncline. Interpretation of the time and intensity of structural development of the Prothro Syncline is based on very sparse well control and limited seismic data (Figure 9-21).

Subsidence in the Prothro Syncline occurred throughout the Cretaceous (Figure 9-21). The amount of downwarping decreased during Pine Island deposition, with the southern flank undergoing the greatest change. The northern flank was most actively downwarped during James deposition, while the southern flank was much more stable. This was probably due to differential stress caused by salt migration into the growing Prothro salt stock. The asymmetrical shape of the basin supports this interpretation (Reese, 1977).

Subsidence continued through the end of the Comanchean, but at a declining rate. Major downwarping occurred again during the early Gulfian. Seismic section D-D' (Figure 9-21) reflects the



SEE FIGURE 9-3 FOR LINE OF SECTION

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1

PREPARED Inge DATE 12/8/80
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APPROVED GHF DATE 12/20/80

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NORTH LOUISIANA STUDY AREA

SEISMIC SECTION D - D'

JOB NO. MV9600

FIGURE 9-21

significant structural development that occurred within the Prothro Syncline during that period.

9.2.3.2.1.12 Prices Syncline: Prices Syncline is the deepest depression in the portion of the Winnfield Basin lying within the study area, and was one of the most structurally active features within the basin (Hessenbruch, 1975). Structural downwarping, accompanied by thickening, probably reached a maximum during deposition of the lower Trinity (Figure 9-22). Structural development decreased steadily throughout the remaining Early Cretaceous and, by the time of Washita deposition, structural development may have reached a minimum. On the basis of volumetric calculations (Hessenbruch, 1975), the volume of salt present in this syncline is interpreted to have been sufficient to account for the amount of uplift of the three surrounding piercement domes (Prices, Chestnut, and Drakes). Hessenbruch's (1975) calculations indicate that salt was migrating out of the syncline into ancestral pillow structures as early as the Late Jurassic. Minor rejuvenations of salt withdrawal are indicated during the Late Cretaceous.

9.2.3.3 Fault Occurrences: Faulting within the study area occurred in response to salt movement and apparently not in response to tectonic forces. Faults exist primarily over the anticlinal structures and are of the normal type, downthrown toward the basins.

The presence of faulting is recognized, where adequate well control exists, by gaps in the stratigraphic section and offset stratigraphy. Near a suspected fault, comparisons have been made between logs, and missing section and offset beds have been evaluated to determine the amount of throw. The extent of a fault through the geologic section is based on what is known about the structural development of the local area in which such faulting occurred. Units most likely to be faulted are those which underwent the most structural deformation in response to salt movement.

9.2.3.3.1 Faulting on the Darley High - A northeast-trending normal fault with approximately 104 meters (340 ft) of displacement has been interpreted on this structure downthrown to the northwest (Figure 9-12). This fault terminates upward in the Upper Cretaceous beds, marking the most recent movement, and is inferred to extend down into the Cotton Valley Group.

9.2.3.3.2 Faulting on Sibley Arch - Four Lower Cretaceous faults have been recognized on the Sibley Arch (Figures 9-7, 9-10, 9-11 and 9-24). The two northern faults are sub-parallel and downthrown toward the adjacent Bistineau Subbasin. The southernmost of the two faults displays 101 meters (330 ft) of displacement in the Ferry Lake interval, and the northern fault shows 55 meters (180 ft) of displacement in the Ferry Lake and Mooringsport intervals. Crowe (1975) reported that the amount of displacement increases with depth along these faults. Seismic data substantiate his observation. The southern fault is inferred to extend from the Hosston into Upper Cretaceous units. The northern fault (Figure 9-23 and 9-24) also extends into the Hosston and may extend upward as far as the Midway Group (Figure 9-15). Its presence at the latter level could reflect recurrent movement along old zones of weakness. It is the only fault detected within the study area which cuts the Midway and is not located within a mile of a salt dome.

Another fault, interpreted from seismic data and located on the southwest edge of Sibley Arch (Figure 9-10), is downthrown to the south and is evidently confined to the Hosston, Sligo, and Pine Island Formations.

9.2.3.3.3 Faulting on Ada Arch - Four faults have been interpreted along the Ada Arch; the three westernmost faults form a horst to the north and a graben to the south (Figures 9-7, 9-11, and 9-24). They are confined to the lower Trinity sections (Ferry Lake-Sligo). Displacement varies from 15 to 30 meters (50 to 100 ft) along these faults.

A fault that lies about 5 km (3 mi) farther east was detected from a study of well logs and confirmed by seismic (Figure 9-12). This fault penetrates units from the Ferry Lake to the Austin Group and has approximately 30 meters (100 ft) of displacement. Another fault, detected on well logs, lies approximately 1.6 km (1 mi) south of the above fault and extends from the Sligo to the Ferry Lake. The displacement on this fault is approximately 46 meters (150 ft).

9.2.3.3.4 Faulting on the Sailes Arch - Two normal faults, sub-parallel to the northeast-southwest trend of the Sailes Arch, are recognized on this structure. The downthrown blocks are on the south flank, toward Kings Syncline (Figures 9-7, 9-9, and 9-11).

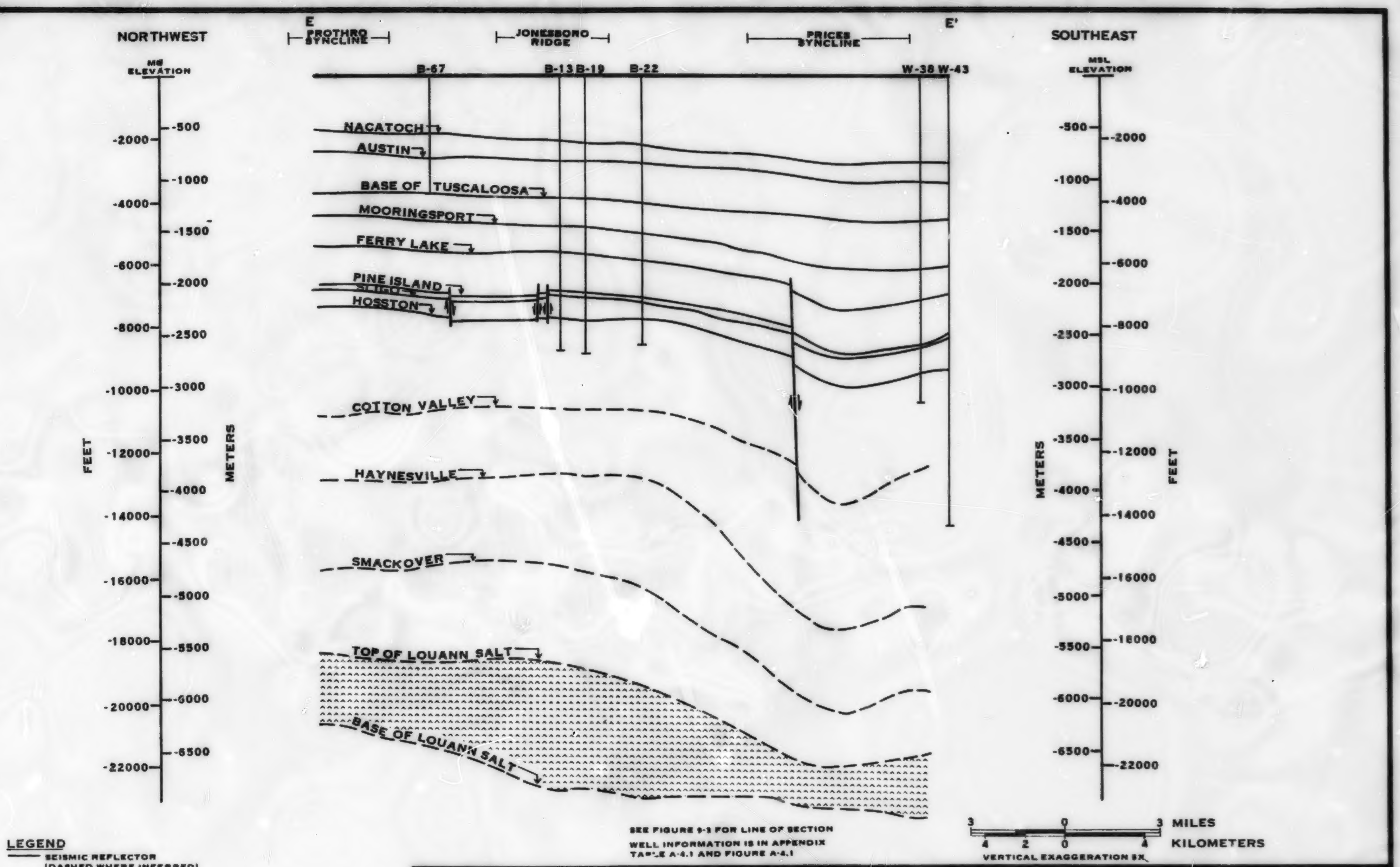
The western fault exhibits 52 meters (170 ft) of displacement on the Sligo horizon and extends from the Cotton Valley Group to the base of the Tuscaloosa.

The eastern fault has similar stratigraphic extent, although it may not extend below the Hosston Formation; no missing section or stratigraphic offset has been detected in the Cotton Valley Group.

Interpretation of seismic data, however, indicates another fault extending from the Ferry Lake to the Austin Group, between the two-above faults (Figure 9-12). Approximately 30 meters (100 ft) of stratigraphic displacement is indicated.

9.2.3.3.5 Faulting on the Lake Bistineau Arch - A long normal fault, sub-parallel to the anticlinal axis, occurs over the Lake Bistineau Arch. Seismic section A-A' (Figure 9-10) indicates the stratigraphic extent to be from the Hosston Formation to the Tuscaloosa. The throw decreases northward along strike from 59 to 29 meters (195 to 95 ft), indicating a rotational motion in the plane of the fault.

9.2.3.3.6 Faulting on the Lucky Arch - A graben system occurs along the northeast-southwest axis of the Lucky Arch (Figures 9-7



SEE FIGURE 9-3 FOR LINE OF SECTION

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1

LEGEND

- SEISMIC REFLECTOR (DASHED WHERE INFERRED)
- ▨ SALT
- // NORMAL FAULT

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APPROVED GHF	DATE 12/23/80

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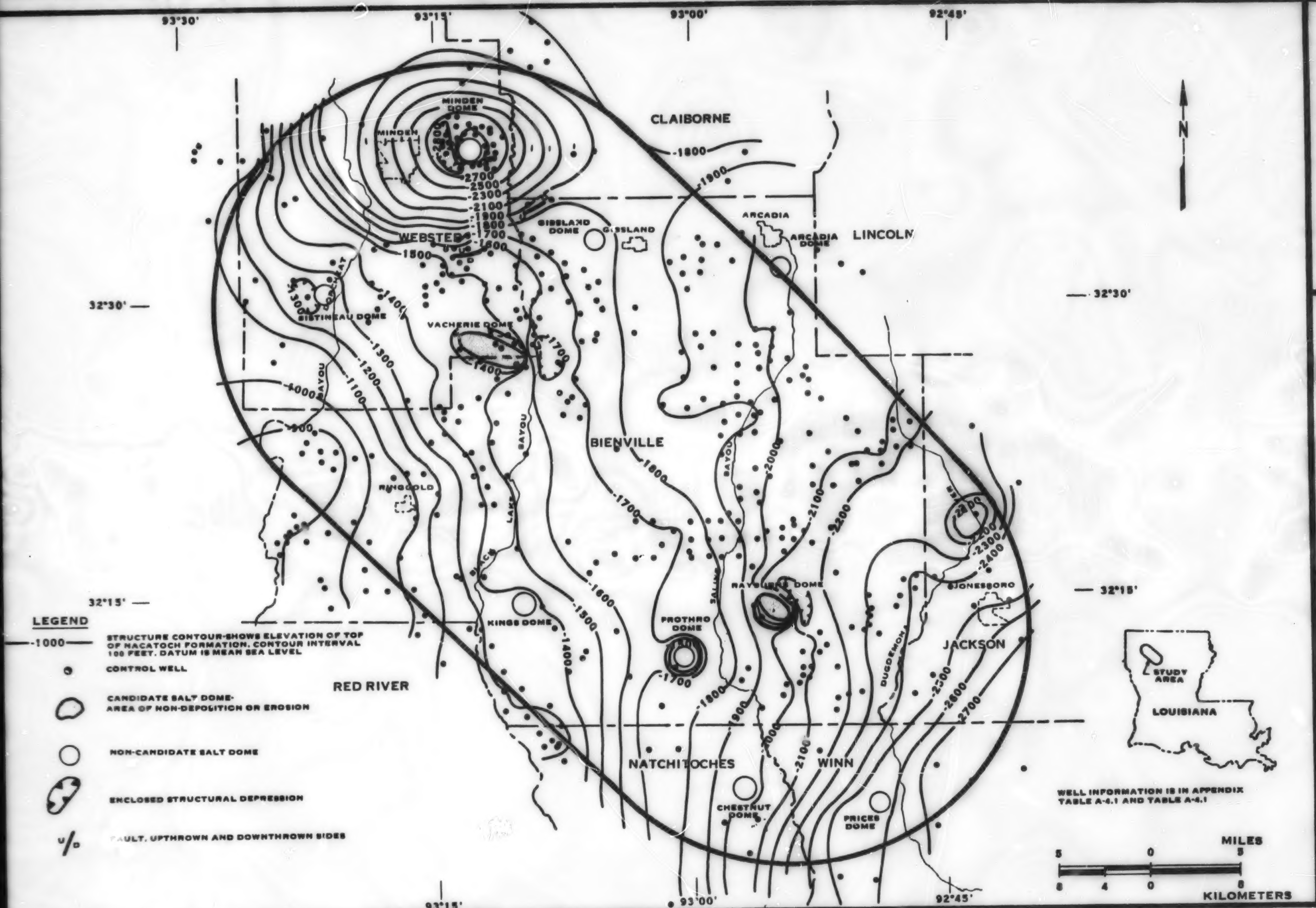
SEISMIC SECTION E - E'

JOB NO. MV9600

FIGURE 9-22



NORTH LOUISIANA STUDY AREA
STRUCTURAL CONTOUR MAP
TOP OF THE NACATOCH FORMATION

FIGURE 9-23

JOB NO. MV9600

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PREPARED Mye DATE 12/18/80
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FIGURE 9-23

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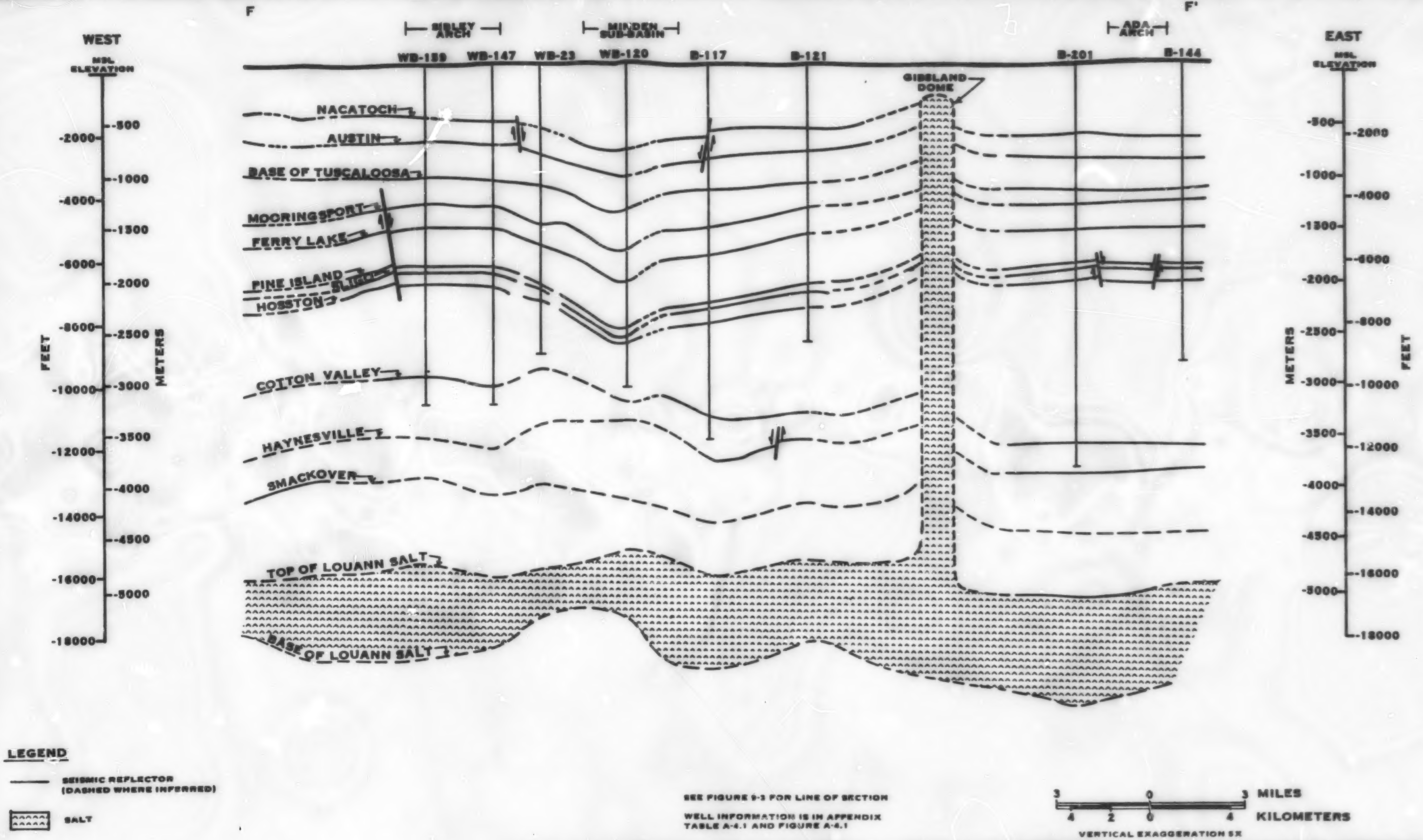

SEE FIGURE 9-3 FOR LINE OF SECTION

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1

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NORTH LOUISIANA STUDY AREA

SEISMIC SECTION F - F'

JOB NO. MV5600

FIGURE 9-24

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and 9-9). The northern fault shows 52 meters (170 ft) of displacement in the Rodessa interval, whereas the southern fault exhibits 94 meters (310 ft) of displacement.

Another fault, located on the eastern flank of the Lucky Arch, is downthrown toward the Rayburns Subbasin. The throw of the fault is approximately 30 meters (100 ft) from the Ferry Lake to the Hosston horizons.

The stratigraphic extent of these faults could not be determined from available well data; however, on the basis of the interpreted structural history of this area, it is judged that these faults are confined to Lower Cretaceous and Upper Jurassic beds.

9.2.3.3.7 Faulting on the Topy Creek Arch - A normal fault, parallel to the northeast-southwest axial trend, is present on the northern flank of the Topy Creek Arch (Figures 9-7, 9-9, and 9-11). It is downthrown toward the Kings Dome and has 44 meters (145 ft) of throw on the James Formation. The fault is believed to extend down into the Cotton Valley Group and it may extend upward as far as the base of the Upper Cretaceous.

Another normal fault, located about 8 km (5 mi) northwest of the Topy Creek Arch, has a throw of 49 meters (160 ft) on the Sligo Formation. By inference, the stratigraphic extent is similar to the adjacent fault on the Topy Creek structure.

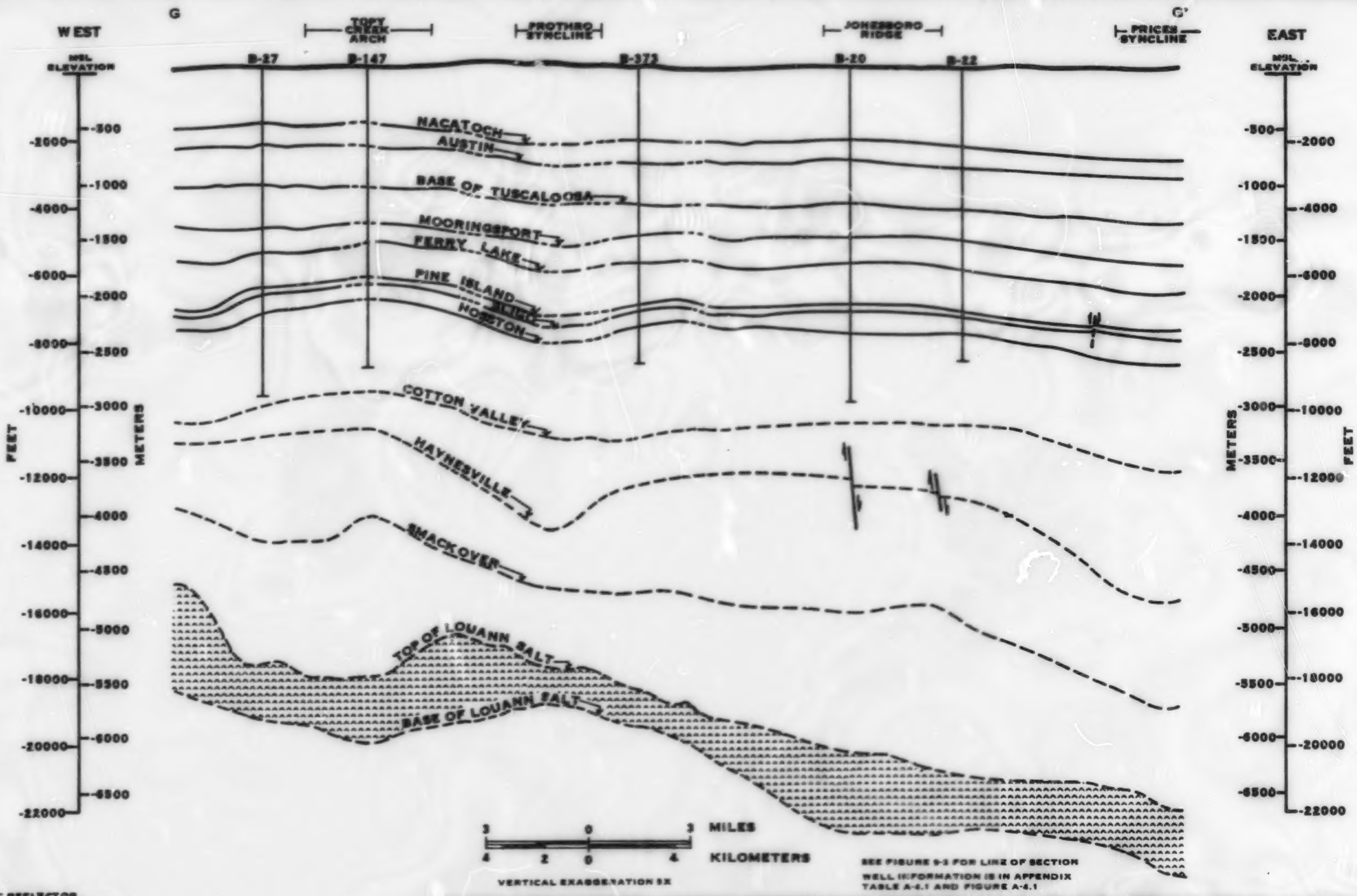
9.2.3.3.8 Faulting on the Jonesboro Ridge - Two faults, which are downthrown toward the Rayburns Subbasin, have been detected on the Jonesboro Ridge. They extend from the mid-Lower Cretaceous down into the Hosston Formation (Figure 9-22). The southern fault exhibits 70 meters (230 ft) of throw on the Sligo horizon; the northern fault exhibits 67 meters (220 ft) of throw on the Rodessa Formation and 61 meters (200 ft) on the James Formation.

Another fault, located approximately 8 km (5 mi) south of the Jonesboro Ridge fault, was inferred from seismic data to be downthrown into Prices Syncline. This fault exhibits approximately 91 meters (300 ft) of throw throughout the Lower Cretaceous and Upper Jurassic (Figure 9-22).

The seismic data indicate a Lower Cretaceous fault approximately 1.6 km (1 mi) south of Rayburn's Dome, between Prothro Syncline and Jonesboro Ridge (Figure 9-22). This fault has a throw and stratigraphic extent similar to those for the two faults located over Jonesboro Ridge, though it is downthrown to the south. The lack of well-log information in the vicinity of this fault precludes confirmation.

Two other faults are indicated on the seismic data to be present on the southwest flank of Jonesboro Ridge (Figure 9-25). The eastern fault shows 61 meters (200 ft) of throw in the Haynesville, and the western fault exhibits 84 meters (275 ft) of throw.

9.2.3.3.9 Other Reported Faulting - During the period 1968-75, the USGS published a series of reports by J. N. Payne on the geohydrology of fresh water aquifers in North Louisiana (Payne,



SEE FIGURE 9-3 FOR LINE OF SECTION

WELL INFORMATION IS IN APPENDIX TABLE A-4.1 AND FIGURE A-4.1

LEGEND

— SEISMIC REFLECTOR (DASHED WHERE INFERRED)

▨ SALT

NORMAL FAULT (DASHED WHERE INFERRED)

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REVISED _______ DATE _______
APPROVED GHF DATE 12/29/80

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SEISMIC SECTION G - G'

JOB NO. MV9600

FIGURE 9-25

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1968, 1970, 1972, 1975). In two of the reports (Payne, 1968 and 1975), the author displayed a 105-km-long (65-mi-long) curvilinear, inferred fault on structural contour maps drawn on the base of the Sparta and the top of the Carrizo Formations. The trace of the fault bypasses Minden, Vacherie, and Rayburn's Domes to the east, and runs the length of the study area.

Payne made the following general reference in his reports to the inferred fault: "As this study is concerned primarily with regional geology and hydrology, faulting has been ignored except where elevation changes are so great and so abrupt that a fault must exist, as in Bienville and Winn Parishes, Louisiana", (Payne, 1968, page A2). He also stated "Faulting such as shown on Plate 3 occurred throughout the Gulf Coast Area", (Payne, 1968, page A3). Payne later commented, "Normal faulting is rather extensive in southern Arkansas, along the eastern flank of the Sabine Uplift in Louisiana, and along the north and northwest limb of the Gulf Coast Geosyncline in Texas" (Payne, 1975, page D2).

Although the fault was presumably interpreted from well logs, well-log sections across the trace of this fault were not included in either paper. Later, Hosman (1978), of the U. S. Geological Survey, included the inferred fault on a map in a report without comment in the text. The one cross section from Hosman's report which passes through the area of the inferred fault did not show the fault.

On two occasions, in a telephone conversation in February, 1979 and in a personal visit in January, 1981, LETCo personnel

[redacted]

communicated with Mr. Payne to determine his basis for interpreting a fault of regional extent in the North Louisiana Salt Basin. Mr. Payne indicated that the basis for his interpretation was an abnormal increase in dip on the contoured horizons which could best be explained by a fault, or a series of en echelon faults. He believed faulting was the result of a combination of salt movement and the development of the Sabine Uplift. He also indicated that the faulting was inferred by him on the basis of well-log data, that it was not well-defined, and that the fault was not identified in the field.

To investigate the evidence for the inferred fault, LETCo evaluated well-log and seismic data and prepared a report of the analysis (Law Engineering, 1981). Well logs were used to prepare structural contour maps on the horizons on which Payne displayed his fault, the base of the Sparta Formation and the top of the Carrizo Formation. The logs were also used to prepare cross sections of shallow Tertiary units across the trace of Payne's fault. Deep cross sections (Cretaceous to Jurassic) were prepared from the seismic lines which intersect the trace of Payne's fault.

Payne, during the previously mentioned personal communication with LETCo personnel, said that he inferred the fault from the abnormally close spacing of the structural contours that he mapped on two Tertiary horizons. The investigation conducted by LETCo suggests that normal spacing is present throughout the area except immediately adjacent to salt domes. No compelling evidence for the reported fault was observed, and throughout much

[redacted]

of its length, the Tertiary beds appear less deformed near the location of the inferred fault than elsewhere in the area of study. The only observed faulting in the area appears to be related to salt intrusion and/or differential compaction of the adjacent sediments.

Echols (1965) and Worley (1962) reported surface faulting in exposed Tertiary formations in portions of the study area. Well-log data in the vicinity of a number of the inferred faults were evaluated and no evidence of subsurface faulting was detected. Evaluation of evidence for faulting on the surface outcrops should be conducted during Location and Site Characterization.

9.2.3.4 Salt Domes and Associated Subbasins: The structural development of Vacherie and Rayburn's Domes is treated in Chapter 10. Locations of the salt domes in the following dicussions are shown in Figure 9-7.

9.2.3.4.1 Minden Dome and Subbasin - Minden Dome is a shallow-piercement feature located in southern Webster Parish (Figure 9-7). It is roughly cylindrical in shape and more than 1,829 meters (6,000 ft) in diameter. The top of the salt lies approximately 579 meters (1,900 ft) below the surface. It is the northernmost dome in the Minden Basin, and the only one within the Minden and Winnfield Basins which has produced commercial quantities of oil and gas.

Well-log data suggest that Minden Dome and its associated subbasin began developing during the Late Jurassic and continued through deposition of the James Formation. By the time of the deposition of the Rodessa Formation, dome growth had reached the diapiric stage and continued through deposition of the Paluxy, Goodland, and Washita Formations. At the latter time, salt probably extruded onto the surface, and strata on the domal flanks collapsed into the surrounding areas from which salt was withdrawn. The Mooringsport Member of the Rusk Formation is nearly double the normal thickness measured from Bellevue Dome, north of the study area, into the Minden Basin, confirming the interpretation of rapid development of the Minden Subbasin during this time.

Deposition was more constant and deformation was less intense during Late Cretaceous and Tertiary time. No major faulting occurred and rim-synclinal deposition was smaller, though more sharply defined and closer to the dome, during this interval. A more complete treatment of the growth history of Minden Dome is presented in Volume I, Chapter 2.

9.2.3.4.2 Bistineau Dome and Subbasin - The size, shape, and precise areal location of Bistineau Dome is not accurately known because only one well has penetrated either caprock or salt. The dome is located in southern Webster Parish, in the Minden Basin (Figure 9-7). The location shown is approximate, and is based on the presence of surface salines and gravity anomalies. The diameter of the dome is estimated at 1.6 km (1 mi) (Spooner, 1926). Depth to salt is approximately 701 meters (2,300 ft).

On the basis of Crowe's (1975) interpretation, thicknesses of the Sligo and lower Trinity intervals indicate little or no subsidence of the Bistineau Subbasin during Sligo deposition, but noticeable downwarping occurred during lower Trinity deposition. A much greater amount of downwarping of the subbasin is indicated during deposition of the Ferry Lake and Mooringsport beds. The Mooringsport member of the Rusk Formation and the Ferry Lake Anhydrite nearly triple in thickness from the Sibley Arch to the center of the subbasin. Based on sparse control of units older than Ferry Lake, interpretation of the data shows no indication of pre-Ferry Lake development of the subbasin; however, seismic data indicate thinning of the Cotton Valley Group across the subbasin. Domal and subbasinal development continued at a diminishing rate during Rusk and Paluxy deposition, and only minor development took place during the Late Cretaceous. There is no indication of development during the Tertiary.

3.2.3.4.3 Gibsland Dome and Subbasin - Gibsland Dome is located in the Minden Basin, in northern Bienville Parish. Ten wells penetrated either caprock or salt, and seven other wells have been drilled within a 3-km (2-mi) radius of the dome. An accurate estimate of the size of the dome cannot be made due to the lack of well control on the north flank; more is known about the south flank area where LPG* storage wells have been drilled. Depth to the top of the salt is approximately 274 meters (900 ft).

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* Liquified petroleum gas

The basinal area around Gibsland Dome appears to be a Lower Cretaceous rim syncline. The major deepening in this subbasin occurred during Sligo, Pine Island, and James deposition, with minor rejuvenation during Rodessa and Ferry Lake deposition. Gibsland Dome developed earlier than did Minden and Bistineau Domes, and at about the same time as the Vacherie Dome. (See Chapter 10 for treatment of the structure of Vacherie Dome.)

Seismic section B-B' (Figure 9-12), which crosses the Gibsland area, shows a thinning of the Cotton Valley Group in the subbasin. This thinning, and that of the same interval in the Bistineau Subbasin, indicates that these basinal areas were Jurassic structural highs.

9.2.3.4.4 Arcadia Dome and Subbasin - Arcadia Dome is in northeastern Bienville Parish. The diameter of the dome is approximately 1.6 km (1 mi), and the depth to the top of salt is approximately 427 meters (1,400 ft). Arcadia Dome is used for LPG storage.

Very little is known about the structural development of Arcadia Dome due to the lack of well data. Although the dome is within the Minden Basin, it is isolated structurally and is difficult to compare with other domes in the basin.

9.2.3.4.5 Kings Dome and Subbasin - Kings Dome is located in southern Bienville Parish. The diameter of the dome is approximately 1.6 km (1 mi), and the depth to salt is 59 meters (192 ft) (Figure 9-20). Reese (1977) displayed a geologic section through the dome which shows a distinct plateau on the northwest flank. Reese postulated that the plateau may have developed as a result of salt dissolution and/or differential movement within the salt.

Initial vertical movement of salt into the Kings stock probably commenced during the Late Jurassic or Early Cretaceous (Figure 9-20). Growth of Kings Dome increased during the Early Cretaceous, then gradually decreased through Late Cretaceous and Tertiary time (Reese, 1977).

9.2.3.4.6 Prothro Dome and Subbasin - Prothro Dome is located in southern Bienville Parish. The diameter of the dome is estimated to be 1.6 km (1 mi) and the depth to the top of the salt is approximately 305 meters (1,000 ft).

Only two wells penetrate Lower Cretaceous units on the flanks of the Prothro Syncline. The data indicate that maximum rim synclinal development occurred during Rodessa deposition and was followed by a decrease in activity until the Late Cretaceous when domal growth apparently intensified. Structural growth decreased sharply during Austin deposition. There is no evidence of structural activity during the late Gulfian or Tertiary.

Rayburn's Dome, which is also in the Prothro Syncline, was undergoing significant growth at the same time. (See Chapter 10 for discussion of the structural development of Rayburn's Dome.)

9.2.3.4.7 Chestnut Dome and Subbasin - Chestnut Dome is located in northern Natchitoches Parish. The size and shape of the dome are not accurately known due to lack of well data. The shallowest drilled depth to the top of the salt is 701 meters (2,300 ft).

A collapse zone, with a net slumpage of over 610 meters (2,000 ft), is situated directly over the crest of the dome. This collapse feature probably resulted from dissolution of the salt spine after deposition of the Cane River Formation and prior to deposition of the Pleistocene terraces (Dinnean, 1958).

During the Late Jurassic and the Early Cretaceous, salt was apparently being withdrawn laterally out of Prices Syncline into Chestnut Dome and the other surrounding salt structures. Basinal subsidence had probably reached a maximum prior to the time of Pine Island deposition (Reese, 1977), and decreased thereafter throughout the Cretaceous. No structural growth is evident during the Tertiary.

9.2.3.4.8 Prices Dome and Subbasin - Prices Dome is located in northern Winn Parish. The diameter of the dome is approximately 1.2 km (0.75 mi), and the depth to salt is approximately 396 meters (1,300 ft).

Basinal subsidence and domal uplift probably reached a maximum prior to Pine Island deposition. Throughout the Early Cretaceous, as structural deformation declined in Prices Syncline, the vertical growth on Prices Dome decreased correspondingly. Decreasing rates of structural development occurred during the Gulfian as recorded by the reduction in rim synclinal development. There is an absence of rim synclinal development in the

Midway interval, suggesting a significant reduction, if not cessation, of the rate of domal growth.

9.2.3.5 Remote Sensing Analysis: Lineaments were interpreted from three types of remote sensing imagery: Landsat, color infrared, and radar. Lineaments were mapped on each form of imagery separately and then combined for illustration purposes (Figure 9-26). Lineaments identified within the study area were expressed chiefly through three characteristics: topographic relief (ridges and valleys) with definite linear orientation, controlled drainage (e.g., straight stream segments, chains of lakes and ponds, and variable widths of flood plains), and distinct tonal contrasts (linear boundaries due to vegetation zonation, soil moisture, etc.).

A predominant northwest-southeast trend in lineament orientation is shown in Figure 9-26. This primary orientation is parallel to the secondary drainage channels, which parallel the lithologic strike of the Tertiary strata. A secondary trend of northeast-southwest-oriented lineaments is also apparent in Figure 9-26. This trend roughly parallels the primary, north-northeast to south-southwest-oriented drainage features in the study area and corresponds to lower-order drainage features. Areas of maximum local relief (30 to 122 meters (100 to 400 ft)) in the study area exhibit a higher density of lineaments.

The good correspondence between dominant lineament trends, drainage, and outcrop patterns, tends to support the thesis that the study area has been tectonically stable since the Tertiary.

The Sabine Uplift to the west was last active during the Tertiary and seems to control the outcrop and drainage patterns in the study area. Quaternary domal stability is also suggested by the absence of major regional lineaments in proximity to the domes (Lewis, 1978).

9.2.4 SEISMICITY: The records of historic earthquakes in the region were compiled, evaluated, and then compared with tectonic and nontectonic features to determine if any correlations exist. Since no positive tectonic correlations were found, the concept of seismotectonic regions was developed for a seismic risk analysis of the study area. The seismic risk analysis identifies the maximum-credible earthquake, return period, probability of occurrence, and design earthquakes.

9.2.4.1 Historic Seismicity: The North Louisiana Salt Basin is located in a region of low seismic activity. Figure 9-27 illustrates the locations of the epicenters of the historic earthquakes which have occurred within the study region. Appendix Table G-1.1 elaborates on the details of each earthquake.

There have been 26 historic earthquakes with intensities of IV-V MM (Modified Mercalli) or greater within a 322-km (200-mi) radius of the study area. These historic events include 1 IV-V MM, 19 V MM, 1 V-VI MM, 3 VI, 1 VI-VII, and 1 VII MM intensity earthquakes.

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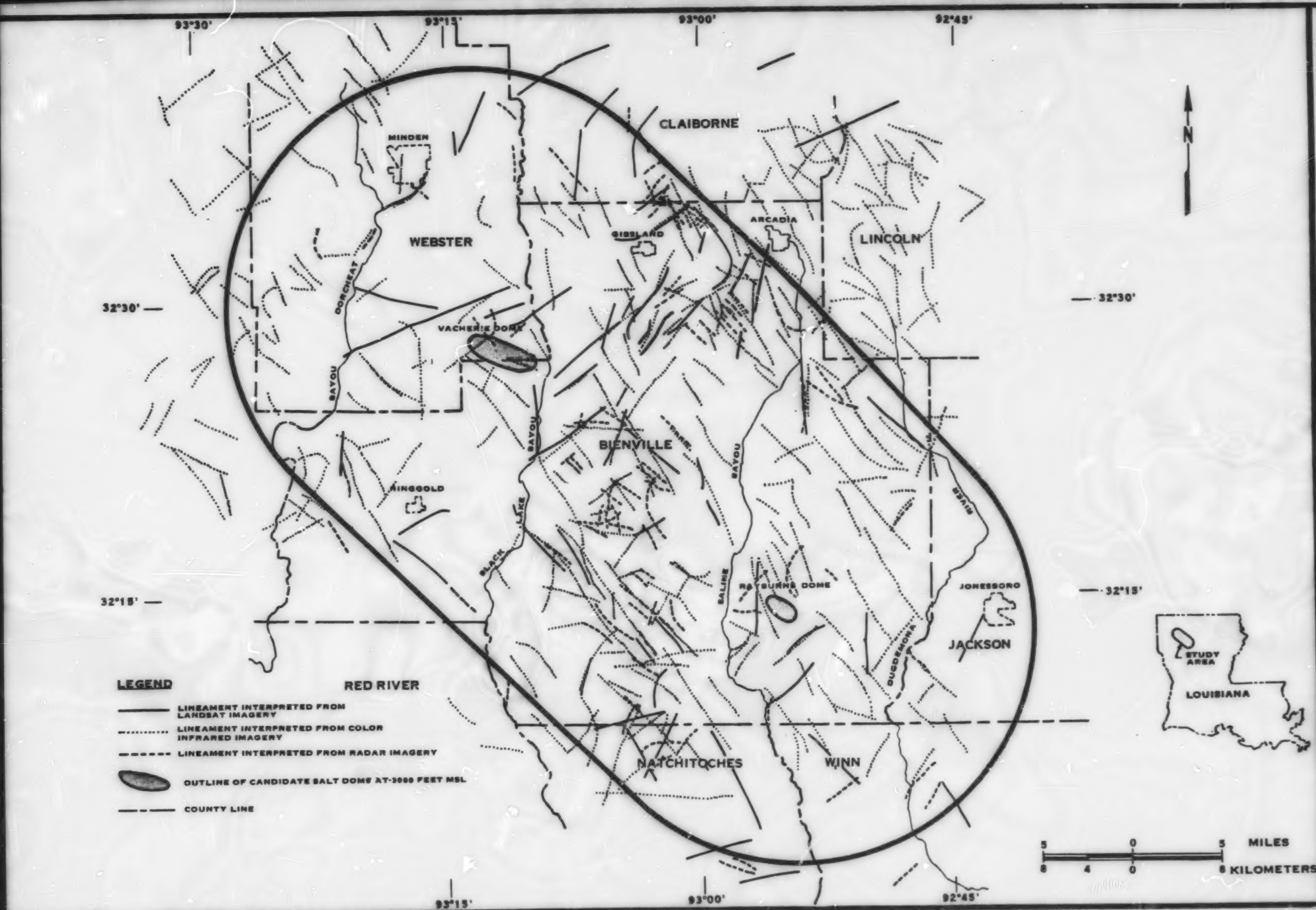

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NORTH LOUISIANA STUDY AREA
LINEAMENT MAP

JOB NO. MV 9600

FIGURE 9-26

FIGURE 9-26

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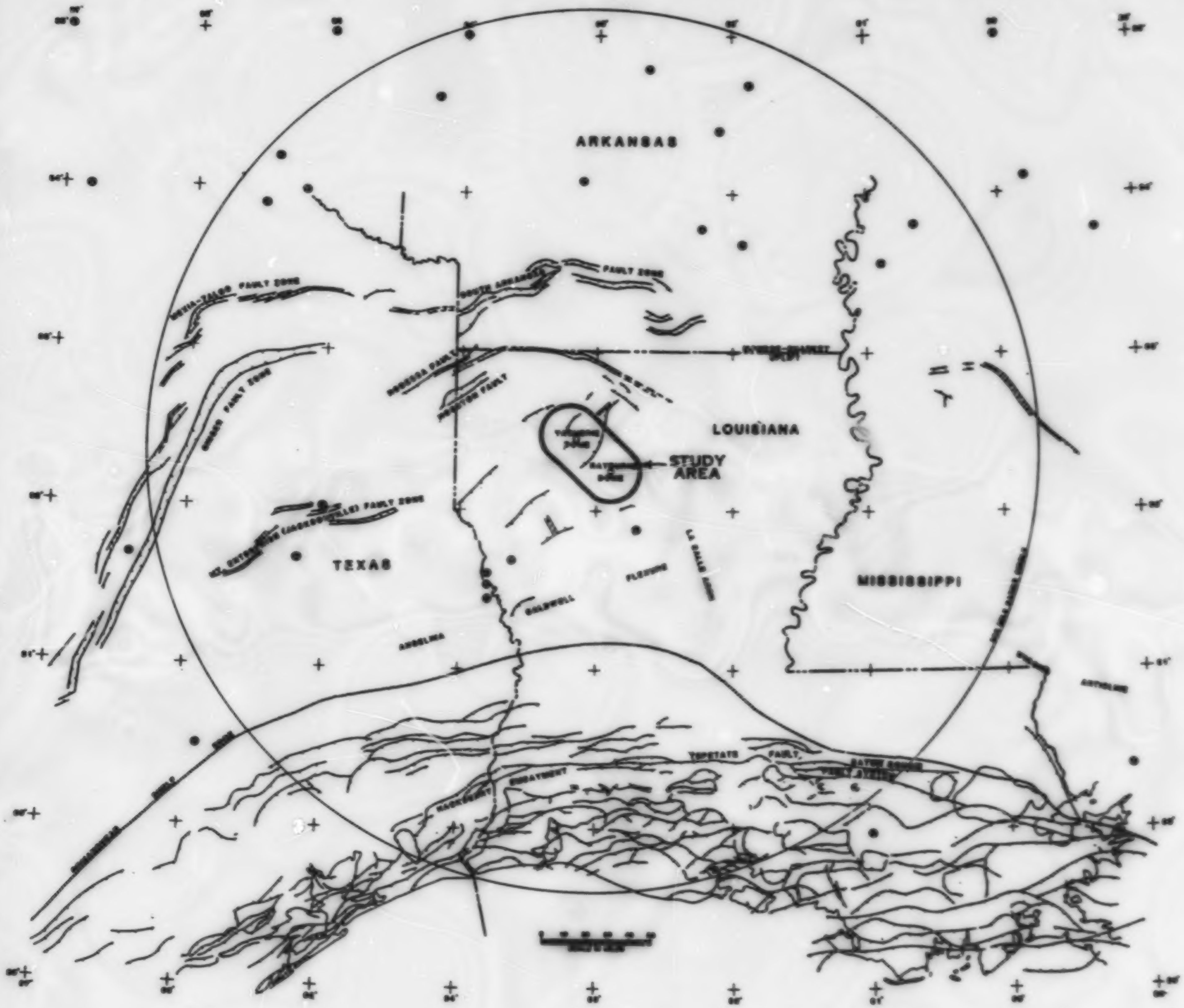

LEGEND

● EARTHQUAKE EPICENTER MODIFIED MERCALLI INTENSITY IV - V OR GREATER (ONE OR MORE EVENTS)

NORMAL FAULT, HACHURED ON DOWNTHROWN SIDE.

INFORMATION ON EACH EVENT IN TABLE 9-3

BASE FROM GCAGS AND AAPG TECTONIC MAP OF THE GULF COAST REGION, USA (1972).

EPICENTER REFERENCES IN APPENDIX TABLE G-1.1

NORTH LOUISIANA STUDY AREA
LOCATION MAP OF EPICENTERS

FIGURE 9-27

JOB NO. MV9800

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COAST SALT DOMES

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APPROVED GHE DATE 12/23/80

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FIGURE 9-27 [redacted]

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9.2.4.2 Regional Tectonics and Seismicity: The lack of correspondence between regional tectonism and seismicity, discussed in Chapter 2 (Volume I), alters the basic approach to evaluating seismicity of the Gulf Coast Basin. This discussion of the seismicity of the North Louisiana Study Area refines our understanding of local historic earthquakes and their association with tectonic structures that extend into the study area.

9.2.4.3 Correlation of Epicenters: An evaluation was made to attempt correlation of reported earthquake epicenters with faults, fault zones, other geologic structures, storms, reservoirs, explosions, and oil and gas fields. Correlations that have been tentatively established with oil and gas fields are discussed below.

Figures 9-6 and 9-27 illustrate the known major geologic structures in and around the North Louisiana Salt Basin. These geologic structures are discussed in Volume I, Chapter 2, and Section 9.2.3 of this report. None of the faults are known to be capable of generating earthquakes. However, from Figure 9-27 earthquakes are known to have occurred in the region, generated by movement along faults in competent rock. It is possible that the shocks are being generated by faults in deep basement rock which have not been mapped.

The injection and withdrawal of fluids in the subsurface have been demonstrated to induce earthquakes (Lee, 1978). The production of oil and gas involves the extraction of fluids (oil, gas, water) and the reinjection of fluids (water, brine) to enhance recovery during declining production. Extraction of fluids will cause subsidence (Sellards, 1930) and the consequent reorientation of subsurface stresses. Injection of fluids causes increased hydrostatic stresses, resulting in decreased cohesion values along existing fault planes, and in local uplift. Both extraction and injection, and especially both operations simultaneously, may cause locally felt earthquakes. Therefore, locally felt (<1,000-km^2 (386-mi^2)) earthquakes within the study area were evaluated to determine whether correlations exist with oil and gas production.

9.2.4.3.1 Epicenter Correlation within Oil and Gas Fields - Oil and gas production began in the North Louisiana Salt Basin about 1930. Locally felt earthquakes during the post-1930 period were selected from North Louisiana Appendix Table G-1.1 for evaluation of oil and gas production-related seismicity. The events below were selected as suspect.

9.2.4.3.2 Winnfield, Louisiana, September 20, 1947 - Docekal (1970) reported "a sharp jar broke waterpipes in three parts of Winnfield, Louisiana, and shook houses". This earthquake was reported in the Alexandria Daily (September 21, 1947), Alexandria, Louisiana, and in the U.S. Coast and Geodetic Survey (1967) archival records at the Federal depository, Franklin and Franconia, Virginia, as having an epicentral intensity of IV-V MM. It was probably a very shallow-focus event since no shock was recorded at any of the existing stations. The estimated epicentral location was 3 km (2 mi) southwest of Winnfield, 1.6 km (1 mi) southeast of Winnfield Salt Dome, 5 km (3 mi) west of Cedar Creek Salt Dome, and 14 km (9 mi) southeast of the Calvin Oil and Gas Field, which had been producing since 1942. The earthquake may have been induced by oil and gas production, or by ground-water extraction and/or mining activities at the Winnfield Salt Dome.

9.2.4.3.3 Louisiana-Texas Border, April 23rd - August 16th, 1964 - According to U.S. Earthquakes (Von Hake and Cloud, 1966), over a dozen shocks were felt during a 4-month period along the Louisiana-Texas border south of Shreveport, Louisiana. The epicentral locations (North Louisiana Appendix Table G-1.1) of these events are within a large oil and gas production area. The nearby fields and initial productive dates are as follows: Kilgore Slough, 1956; Converse, 1942; Pleasant Hill, 1927; Ajax, 1941; Spring Ride, 1931; Zwolle, 1928; Blue Lake, 1928; Pendleton-Many, 1958; Ft. Jessup, 1961; Negreet, 1946; and Rattan, 1964. All of these fields were within 8 km (5 mi) of at least one epicentral location. Production at any of these fields may have contributed to the seismic activity. The earthquakes may have occurred over, or just to the south of, the Angelina-Caldwell Flexure.

9.2.4.4 Seismic Risk Analysis: No definite correlations were made between structures and documented earthquakes; accordingly, analyses based on seismotectonic regions were used to establish seismic risk. Seismotectonic regions are areas of similar tectonic history and seismic activity (Volume I, Chapter 2). The Interior Salt Basin Seismotectonic Region (ISBSR) has an established maximum earthquake intensity of VI MM. This particular event could have been generated anywhere within the ISBSR or attenuated from the neighboring Ouachita Seismotectonic Region to the north. However, none of the other seismotectonic provinces could contribute an attenuated ground motion equal to an intensity VI MM earthquake.

A return period and probability-of-exceedence calculation was made for the candidate domes in the North Louisiana Salt Basin. Figure 9-28 gives the results of this analysis.

In summary, seismic activity in the North Louisiana Study Area is low. The candidate salt domes in the study area can expect a maximum ground motion intensity of VI MM. No tectonic features were identified as capable of generating earthquakes.

9.3 MINERAL RESOURCES OF THE NORTH LOUISIANA STUDY AREA

Development of mineral resources in any ara is dependent on the location and availability of profitable markets, the state of mining and extraction technology, and the abundance of the same resources in other areas, among other things. Mineral resources presently being exploited within the North Louisiana Study Area include oil and gas, as well as sand and gravel. Mineral resources that have been exploited in the past, or could possibly be utilized in the future, include salt, anhydrite, gypsum, lignite, ironstone, clay, and limestone.

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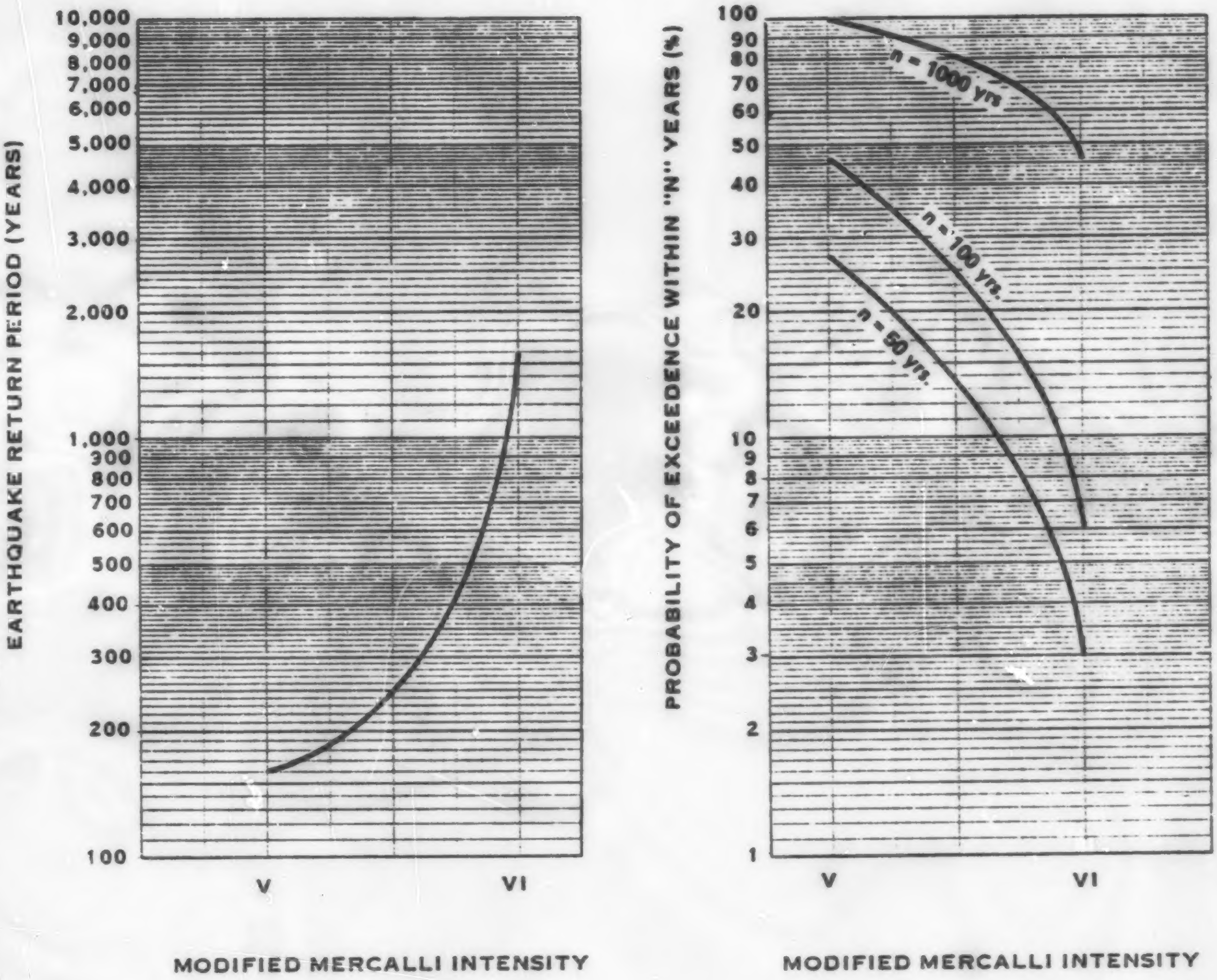

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APPROVED GHF	DATE 12/29/80

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

NORTH LOUISIANA STUDY AREA
EARTHQUAKE RETURN PERIOD
AND PROBABILITY OF
EXCEEDENCE CURVES

JOB NO. MV9600 FIGURE 9-28

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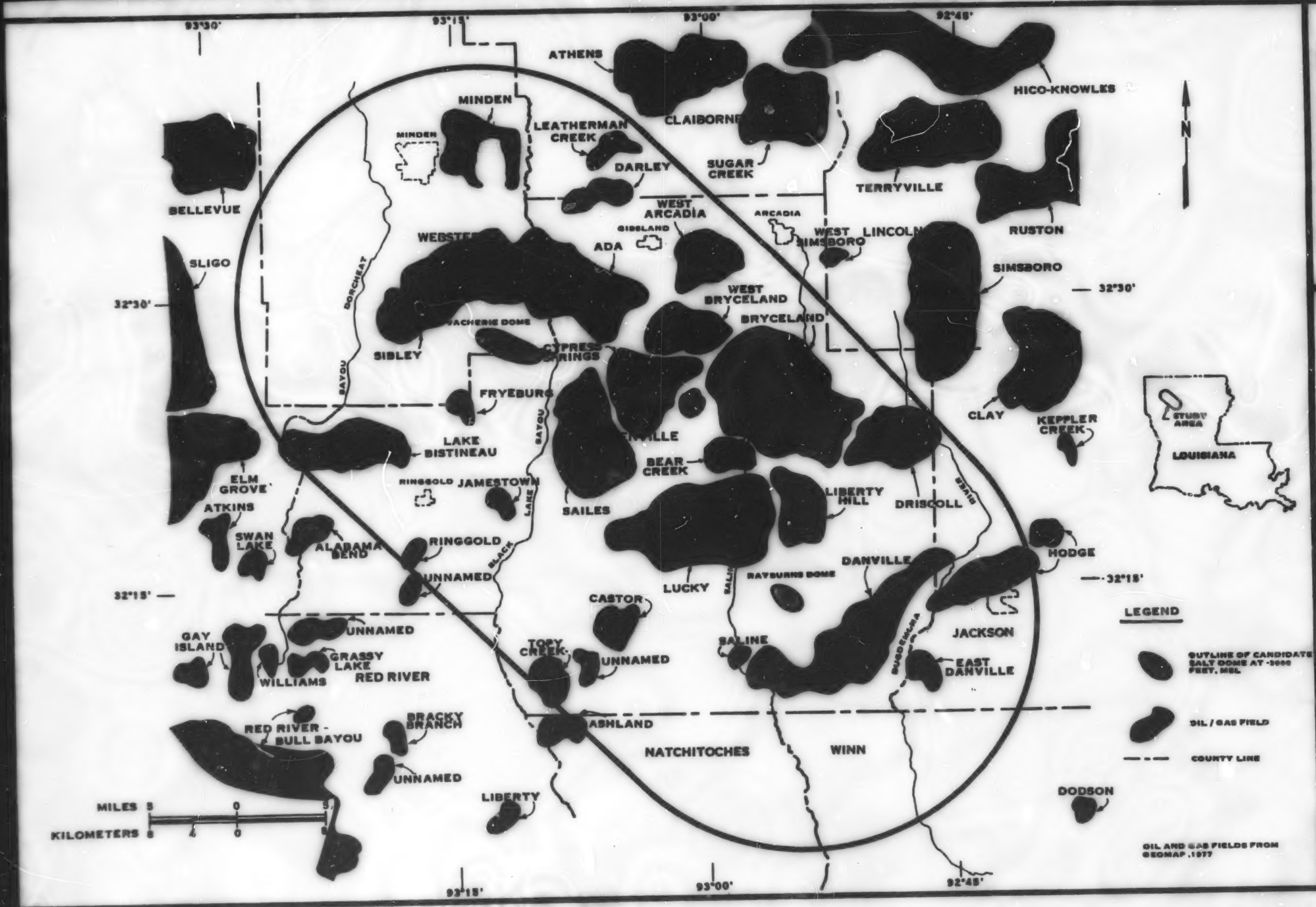
9.3.1 PETROLEUM RESOURCES: Petroleum production is primarily from Lower Cretaceous and Upper Jurassic strata. Of the 23 oil and gas fields within the study are (Figure 9-29), 11 had declining production from 1973 to 1977 (the latest period for which statistics are available), 4 remained constant, 3 had increased production, 4 had no reported production, and 1 field was new (Table 9-2) (Louisiana Department of Conservation, 1973, 1974, 1975, 1976, 1977). Three fields --West Bryceland, Fryeburg, and Saline --were temporarily abandoned between 1952 and 1969, but production was later resumed.

The proven size (as of 1976) of the producing fields within the study area averages 3,440 hectares (8,500 acres) and varies from 32 hectares (80 acres) (Castor and Ringgold Fields) to 18,009 hectares (44,500 acres) (Sailes Field). Ada, Bear Creek, Lucky, and Sibley Fields are also of considerable size, between 7,033 and 11,998 hectares (17,000 and 29,000 acres) each.

The major petroleum production has come from the Lower Cretaceous Sligo and Hosston Formations, with lesser amounts from the Upper Jurassic Cotton Valley Group and other Lower Cretaceous units, the James and Rodessa Formations, in particular. Most current exploration and production focuses on depths of 1,829 to 3,658 meters (6,000 to 12,000 ft). Production in the Sligo Formation is from the porous, oolitic Pettet zone, which is locally a biogenic facies. Production in the Hosston Formation is from numerous bar sands (Holloway, 1963).



NORTH LOUISIANA STUDY AREA

OIL AND GAS FIELD MAP

JOB NO. MV 9600

FIGURE 9-29

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED J.L.C. DATE 1/30/80
REVISED JMC DATE 12/18/80
REVISED BCP DATE 11/21/81
APPROVED GHE DATE 12/23/80

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FIGURE 9-29

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TABLE 9-2
NORTH LOUISIANA STUDY AREA
Petroleum Production Statistics

1 of 3

Field Name/ Parish		Producing Formations	Oil and Gas Condensate Production				Gas Production				Production Status	
			Crude Oil		Condensate		Dry Gas		Casinghead Gas		Oil	Gas
			BBLS 1977	Commulative BBLS 1/1/78	BBLS 1977	Commulative BBLS 1/1/78	MCF 1977	Commulative MCF 1/1/78	MCF 1977	Commulative MCF 1/1/78	1973 - 1977	1973-1977
Ada/Webster, Bienville	8/44	Rodessa	85,512	4,249,994	24,419	960,352	12,587,835	420,911,360	3,916	10,353,797	Declining	Increasing
Arcadia West/ Bienville	12/64	Hosston, Pettet			616	19,954	186,296	8,632,319				Declining
Bear Creek/ Bienville	3/37	Pettet, Hosston, Rodessa, Cotton Valley		7,866	20,554	1,264,143	10,076,916	492,386,083			NP 73-77	Declining
Bryceland/ Bienville	5/47	Hosston			1,855	105,767	695,340	47,992,693				Decreasing
Bryceland West/ Bienville	3/52	Hosston	20	12,098	18,989	244,222	8,857,864	97,595,127		88,317	Declining	Declining
Castor/ Bienville	12/48	Hosston			1,565	1,870	315,662	782,855				NP 73-76
Cypress Springs/ Bienville	10/54	Pettet		203,896						212,109	NP 73-77	NP 73-77
Danville/ Bienville	2/66	Hosston			10,029	72,322	17,491,609	110,929,459				Constant

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NP - No Production

100

TABLE 9-2
NORTH LOUISIANA STUDY AREA
Petroleum Production Statistics

Field Name/		Producing	Oil and Gas Condensate Production				Gas Production				Production Status	
			Crude Oil		Condensate		Dry Gas		Casinghead Gas		Oil	Gas
Parish		Formations	BBLS 1977	Cummulative BBLS 1/1/78	BBLS 1977	Cummulative BBLS 1/1/78	MCF 1977	Cummulative MCF 1/1/78	MCF 1977	Cummulative MCF 1/1/78	1973 - 1977	1973-1977
Darley/ Claiborne, Bienville	10/55	Tokio		52,890		4,164		3,771.026			NP 73-77	Declining
Driscoll/ Bienville	4/36	Rodessa, James Pettet, Hosston, Massive Anhydrite	17	4,634	1,613	135.025	1,708.327	60.618.724		686	Declining	Declining
Fryeburg/ Bienville, Webster	10/69	James			234	1,474	57,605	330.468				Constant
Hodge/ Jackson	11/61	Hosston			302 (1976)	5,959 (1/1/77)	1,751,863 (1976)	33,476,854 (1/1/77)				Declining
Jamestown/ Bienville	5/75	James			91	91	18,207	18,207				New Field
Lake Bistineau/ Bienville, Bossier	2/16	Ozan, Tokio Paluxy, Sligo, Hosston, C.V.		197	213	53,180		137,934,214			NP 73-77	NP 74-77
Leatherman Creek/ Claiborne	7/74	Sligo, Hosston, Cotton Valley	22,000	54,751	31,920	36,251	4,027,685	4,996.361	2,918	2,918	Declining	Increasing

NP = No Production

TABLE 9-3
NORTH LOUISIANA STUDY AREA
Petroleum Production Statistics

3 of 3

Field Name/ Parish		Producing Formations	Oil and Gas Condensate Production				Gas Production				Production Status	
			Crude Oil		Condensate		Dry Gas		Casinghead Gas		Oil	Gas
			BBLS 1977	Cummulative BBLS 1/1/78	BBLS 1977	Cummulative BBLS 1/1/78	MCF 1977	Cummulative MCF 1/1/78	MCF 1977	Cummulative MCF 1/1/78	1973 - 1977	1973-1977
Liberty Hill/ Bienville	3/54	Hosston			140	32,347	183,113	31,134,466				Declining
Lucky/ Bienville	6/43	Pettet	16,562	1,139,658	9,885	617,816	3,985,101	206,980,704		150,269	Declining	Declining
Minden/ Webster	5/57	Paluxy	56,422	3,229,416	5,862	1,155,921	2,128,950	65,766,377	134,119	4,617,101	Constant	Constant
Ringgold/ Bienville	1/76	Hosston			213	355	28,102	38,489				Increasing
Salles/ Bienville	5/45	Pettet	1,950	53,870	6,036	127,829	2,088,626	23,301,264		490,916	Declining	Declining
Saline/ Bienville	10/47	James						20,087				NP 74-77
Sibley/ Webster	5/36	Rodessa	2,153	669,371	19,022	771,786	8,192,604	255,394,731	43	3,388,922	Declining	Constant
Topy Creek/ Bienville	8/55	Tuscaloosa	8,119	836,948							Declining	

NP = No Production

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The gravity of hydrocarbons produced from fields in the North Louisiana Study Area varies from approximately 20° to 60° API.* Average gravity values for the Sligo Formation (40° API), the Hosston Formation (51° API), and the Cotton Valley Group (53° API) illustrate the general trend of decreasing specific gravity (increasing API gravity) with depth. Crude oil in the higher API gravity ranges (lower specific gravity) is generally more easily recovered and usually has a greater calorific and economic value.

Oil and gas traps are classified as structural, stratigraphic, and a combination of the two. Most production within the study area occurs along faulted, arched structures that are genetically related to salt pillowing (see Section 9.2.3). Some arches (for example, those making up Bear Creek, Bryceland, and Lucky Fields) exhibit over 122 meters (400 ft) of closure on Lower Cretaceous formations (Holloway, 1963; Gaffney, 1963). The porous Pettet zone and Hosston bar sands are in some places laterally discontinuous and form stratigraphic traps.

Salt domes commonly provide the necessary structural and stratigraphic traps for oil and gas accumulation but, with the exception of Minden Dome, North Louisiana domes have so far proven to be barren. Although potential reservoir rocks are present around the domes, accumulation may not have occurred at a given dome because: (1) the oil and gas may have migrated past the dome before a trap was formed in a particular formation; (2) a rim syncline may have developed and blocked fluids from migrating to the salt dome; or (3) oil and gas accumulations near the salt dome may have been drained by reversal of dipping beds through later domal movement or may have leaked through related faults (Netherland, Sewell and Associates, Inc., 1975).

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*American Petroleum Institute has published gravity standards used in the petroleum industry.

The extensive petroleum production at Minden Dome (Table 9-2) may be due to the unique structural and stratigraphic developments during its growth compared with that of other North Louisiana domes. Most production is from traps formed by steeply dipping, truncated, Lower Cretaceous and Upper Jurassic formations overlain by the Kiamichi shale (Law Engineering, 1978). Angular unconformities of this magnitude are not known to exist at any of the other domes in the North Louisiana Salt Dome Basin. The area of uplift and the related petroleum entrapment area, important factors governing the amount of accumulation (Halbouty, 1979), were much greater during the Early Cretaceous at Minden than at Vacherie or Rayburn's. The area of uplift can be approximated by mapping the area of stratigraphic thinning around each dome during a given time interval (Figure 9-13).

9.3.2 SAND AND GRAVEL: Sand and gravel deposits occur primarily in the substrata of Quaternary terraces and in alluvium in stream valleys. Sand can also be found at or near the surface in unconsolidated Eocene beds. The Quaternary terrace sand and gravel deposits characteristically contain chert, probably derived from Paleozoic outcrops in Arkansas and Oklahoma (Martin and others, 1954). Much of the terrace gravel has since been eroded from upland areas and redeposited in the lowlands flanking Pleistocene and Recent stream courses.

The statistics of current exploitation of sand and gravel are difficult to determine because permits are not required for gravel pit operations in Louisiana; therefore, no official records exist. Webster Parish has in the past been a significant producer of sand and gravel in the state of Louisiana (Martin and others, 1954). Because of the general abundance of sand and gravel in the Gulf Coast Region, it is doubtful, particularly with increasing transportation costs, that deposits within the North Louisiana Study Area will become a significant export commodity (Murray, 1979). However, the prospects of sand and gravel exploitation for local use are good. The only significant, active, commercial operation is Dresser Industries' silica mine about 3 km (2 mi) north of Vacherie Dome (Martinez and others, 1977), where glass sand from the Eocene Sparta Formation is being mined.

9.3.3 SALT: Rock salt, which occurs as both bedded and domal deposits, is probably the most abundant mineral resource. Although the bedded salt is too deep to be profitably mined, the ten salt domes in the study area are shallow enough to be mined either by conventional methods or by solution mining. At present, rock salt is not being commercially exploited at any of the North Louisiana domes; however, salt was mined at Winnfield Dome, south of the study area, from 1932 until 1965. (See Volume I for a discussion of Winnfield Dome.)

Operations in the past, however, have utilized saline ground water, above and around several of the domes, to produce salt.

During the Civil War period, salt water from shallow wells was evaporated in large kettles at Bistineau, Rayburn's, Prices, and Kings Domes to provide salt for the Confederacy and for local consumption (Spooner, 1926). All of these operations had ceased by 1900.

The general abundance of salt elsewhere will probably preclude exploitation of domal salt in the area except possibly at very shallow domes (salt at Rayburn's and Kings Domes is less than 61 meters (200 ft) from the surface). Storage of LPG or crude oil in solutioned cavities is a feasible utilization of the deeper domes. LPG storage facilities are currently in operation at Arcadia and Gibsland Domes.

9.3.4 LIGNITE: Lignite occurs primarily in the Wilcox Group, with sparse amounts in the Sparta and Cockfield Formations (Meagher and Aycock, 1942). Beds of the Wilcox Group are exposed at the southwest edge of the study area, dipping to the northeast (Figure 9-5). Accordingly, depth from the ground surface to the top of the Wilcox varies from 0 to almost 304 meters (1,000 ft).

Although exploration for lignite has been conducted in northwest Louisiana, it is difficult to evaluate the resource potential within the study area. Thin beds of lignite have been found at the surface (Meagher and Aycock, 1942) and at fairly shallow depths near Vacherie and Rayburn's Domes (Martinez and others, 1977, 1978). However, the greatest potential appears to be in DeSoto and Sabine Parishes, approximately 40 km (25 mi) southwest of the study area. Here, 1 to 2-meter (5 to 7 ft) thick, laterally continuous beds of moderate grade lignite occur near the surface (Roland and others, 1976). The thick lignite of DeSoto and Sabine Parishes occurs in the lower Wilcox outcrop and shallow subsurface and, if present, downdip would be found within the study area at substantial depth.

If it is assumed that an overburden-to-lignite thickness ratio less than 15:1 is required for commercial exploitation (Roland and others, 1976), it is questionable whether lignite would be a profitably exploitable resource in the study area. Ultimately, however, gasification of deeper lignite may become feasible.

9.3.5 IRON ORE: Iron ore of variable grade occurs in clay-ironstone deposits and in iron-cemented sands and gravels. The clay ironstone occurs along the upper Cook Mountain-lower Cockfield outcrop belt in the northeast part of the study area (Figure 9-5). Eocene sideritic glauconite beds alter during weathering to brown ore, which consists of clay with limonite in veins or seams which form ledges in the weathered outcrop. The veins of limonite have an average iron content of 47.5 percent, and the parent sideritic glauconite veins (green ore) have an average iron content of 34.8 percent (Durham, 1964).

Iron-cemented sands and gravels occur throughout most of the study area in both Quaternary and Tertiary deposits. The cementation occurs by precipitation of iron oxide from ground water in the pore spaces of sediments (Martinez and others, 1978). Analyses to calculate the iron content of these sediments have not been conducted.

It is questionable if the iron-cemented sands and gravels would assay as iron ore; however, the use of clay-ironstone deposits is quite feasible (Durham, 1964). The clay ironstone occurs at the surface and, therefore, could be strip-mined easily. Its only current use is for local road metal.

9.3.6 OTHER RESOURCES: Other mineral resources with only limited potential include gypsum, anhydrite, limestone, and clay. Gypsum, anhydrite, and limestone occur as caprock above salt domes. With the exception of Rayburn's and King's Domes, and possibly Prothro and Bistineau Domes, the caprock deposits are too deep to be economically mined. An unsuccessful attempt was recently made by the T. L. James Co. to quarry limestone from the caprock at Rayburn's Dome for use as aggregate. Uncontrollable flow of saline ground water into exploratory excavations, as well as insufficient quantities of shallow limestone, made the endeavor unfeasible, so the site was abandoned (Martinez and others, 1980) (see Section 10.2.3.3).

Limestone also occurs above some domes as inliers of Upper Cretaceous Formations. Low-quality agricultural lime was quarried from outcrops above Rayburn's Dome between 1943 and 1945 (Meade, 1980), and above Prothro Dome in 1945 (Durham and White, 1960; Butler and Jones, 1957). Due to the limited areal extent of the limestone, and its low quality for agricultural or other commercial purposes, it is doubtful that either quarry will be reopened.

Local deposits of clay suitable for pottery, title, or brick may occur within the study area, but most clay deposits that havebeen analyzed lack the proper degree of plasticity (Whittemore, 1929).

9.4 SUMMARY OF THE NORTH LOUISIANA STUDY AREA

The North Louisiana Study Area is in the northern portion of the North Louisiana Salt Basin, which includes Vacherie and Rayburn's Domes. Although the geologic characterization studies were focused on the domes and the surrounding areas, the relationships and influences of the major elements of the geologic framework of the more extensive North Louisiana Salt Basin were also examined.

Existing data, consisting of oil, gas, and water-well logs; seismic-reflection surveys; regional residual gravity-anomaly maps; and geologic maps, were purchased and evaluated. Data specifically acquired for this study consisted of deep borings, ground-level resistivity surveys, remote sensing, gravity models, and a detailed gravity survey over Rayburn's Dome. Geologic cross sections, as well as structural and isopachous contour maps, have been constructed. These data represent the basis for interpretation of the geologic history and present geologic conditions of the study area.

The physiography, including the drainage and geomorphology, is strongly controlled by the regional structure and lithology of stratigraphic units in the North Louisiana Study Area. Modifying this relationship in the study area was the emplacement of salt masses, both shallow and deep, which now appear to have been stabilized. Subbasins that correspond to subregional sedimentary depocenters have been identified within the North Louisiana Salt Basin. Movement and pillowing of the Louann Salt is believed to be responsible for controlling the location of structurally high arches and intervening subbasins.

All of the known faulting which is distributed throughout the study area is related to salt movement and generally can be characterized as minor. In the absence of evidence to the contrary, it is tentatively concluded that there are no active faults within the North Louisiana Study Area.

Seismicity studies determine that the seismic activity for the North Louisiana Study Area is low. The candidate salt domes can expect a maximum ground-surface motion of intensity VI MM. No tectonic features are identified as capable of generating earthquakes.

Major mineral resources of the study area are energy related, consisting chiefly of oil and gas. Exploration and production of these resources is expected to continue with a probable increase in the number of tests of deep horizons.

CHAPTER 9

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10 GEOLOGIC CHARACTERIZATION OF SELECTED DOMES IN THE NORTH LOUISIANA STUDY AREA

The geologic characterization of selected domes within the North Louisiana Study Area includes evaluations of Vacherie and Rayburn's Domes, focusing on the areas within a 8 km (5 mi) radius of the domes.

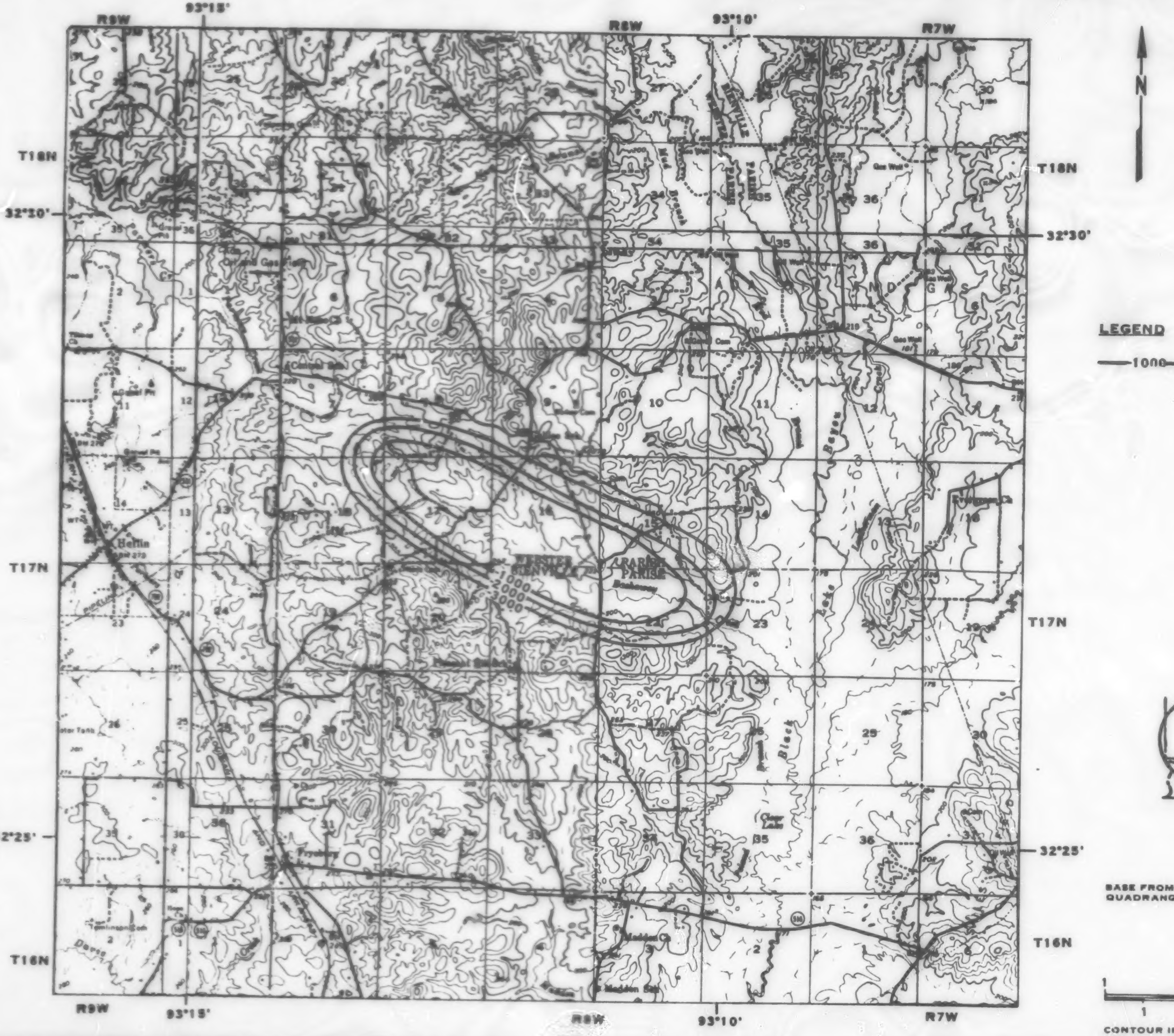
10.1 VACHERIE DOME

Vacherie Dome is located in southeastern Webster and northwestern Bienville Parishes, Louisiana (Figures 9-1 and 10-1). The nearest towns are Heflin (pop. 300), 5.8 km (3.6 mi) to the west; Fryeburg (pop. 100), 6.1 km (3.8 mi) to the southwest; Gibsland (pop. 1,400), 15.8 km (9.8 mi) to the northeast; Dubberly (pop. 200), 8 km (5 mi) to the north; and Sibley (pop. 870), 11 km (7 mi) to the northeast.

Forestry and agriculture are the primary land uses in the area. Wilamette Industries owns approximately 227 hectares (560 acres) at the eastern end of the dome, as well as several large tracts elsewhere in the surrounding area. Continental Forest Industries currently holds leases to approximately 227 hectares (560 acres) that fall within the surface area of 1,105 hectares (2,730 acres) delineated by the -914-meter (-3,000-ft) salt contour. Examination of aerial photographs taken in 1978 indicates that a small area of approximately 40 hectares (100 acres) was being cultivated on the west flank of the dome and a larger area just north of the dome. Potential mineral resources encountered near Vacherie Dome include sand and gravel, rock salt, and lignite. (See section 10.1.3 for a discussion of mineral resources near Vacherie Dome.)

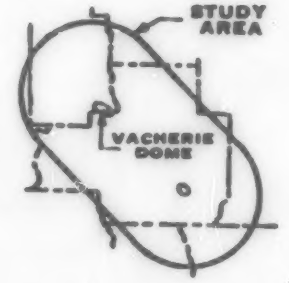
The following sections include interpretations of the geometry of the salt, the near-dome geology, and the mineral resources in the dome vicinity. Figure 10-2 presents the locations of wells from which geophysical logs were obtained, and locations used for collection of resistivity data, both of which were used for interpretation.

10.1.1 DOME GEOMETRY AND COMPOSITION: Gravity modeling of Vacherie Dome indicates that in profile the dome shape is that of a salt ridge with a broad base tapering upward. The flanks have a fairly constant slope of 30° from the vertical to -3,048 meters (-10,000 ft) MSL, below which depth the flanks are essentially vertical (Figure 10-3). In plan-view Vacherie Dome is elliptical with the long axis oriented northwest-southeast (Figures 10-4 and 10-5). In horizontal cross section the dome encompasses 822 hectares (2,031 acres) at -610 meters (-2,000 ft) MSL, 963 hectares (2,379 acres) at -762 meters (-2,500 ft) MSL, and 1,105 hectares (2,730 acres) at -914 meters (-3,000 ft) MSL. Penetrations of the salt are shown on Figure 10-6 and listed in Table 10-1. With the exception of a salt core hole drilled specifically for this project, no wells penetrate the -610 meter (-2000 ft) MSL contour level of the salt within the projection of the contour to the surface.



LEGEND

—1000— STRUCTURE CONTOUR - SHOWS ELEVATION OF TOP OF SALT. INTERVAL 1000 FEET. DATUM IS MEAN SEA LEVEL.



BASE FROM U.S. GEOLOGICAL SURVEY QUADRANGLES, 1:62,500

CONTOUR INTERVAL 20 FEET.
DATUM IS MEAN SEA LEVEL.

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
TOPOGRAPHIC MAP WITH
STRUCTURAL CONTOURS ON THE SALT

JOB NO. MV9600.

FIGURE 10-1

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED ________ DATE 12/12/80
REVISED ________ DATE 1/13/81
REVISED ________ DATE ________
APPROVED GHE DATE 12/23/80

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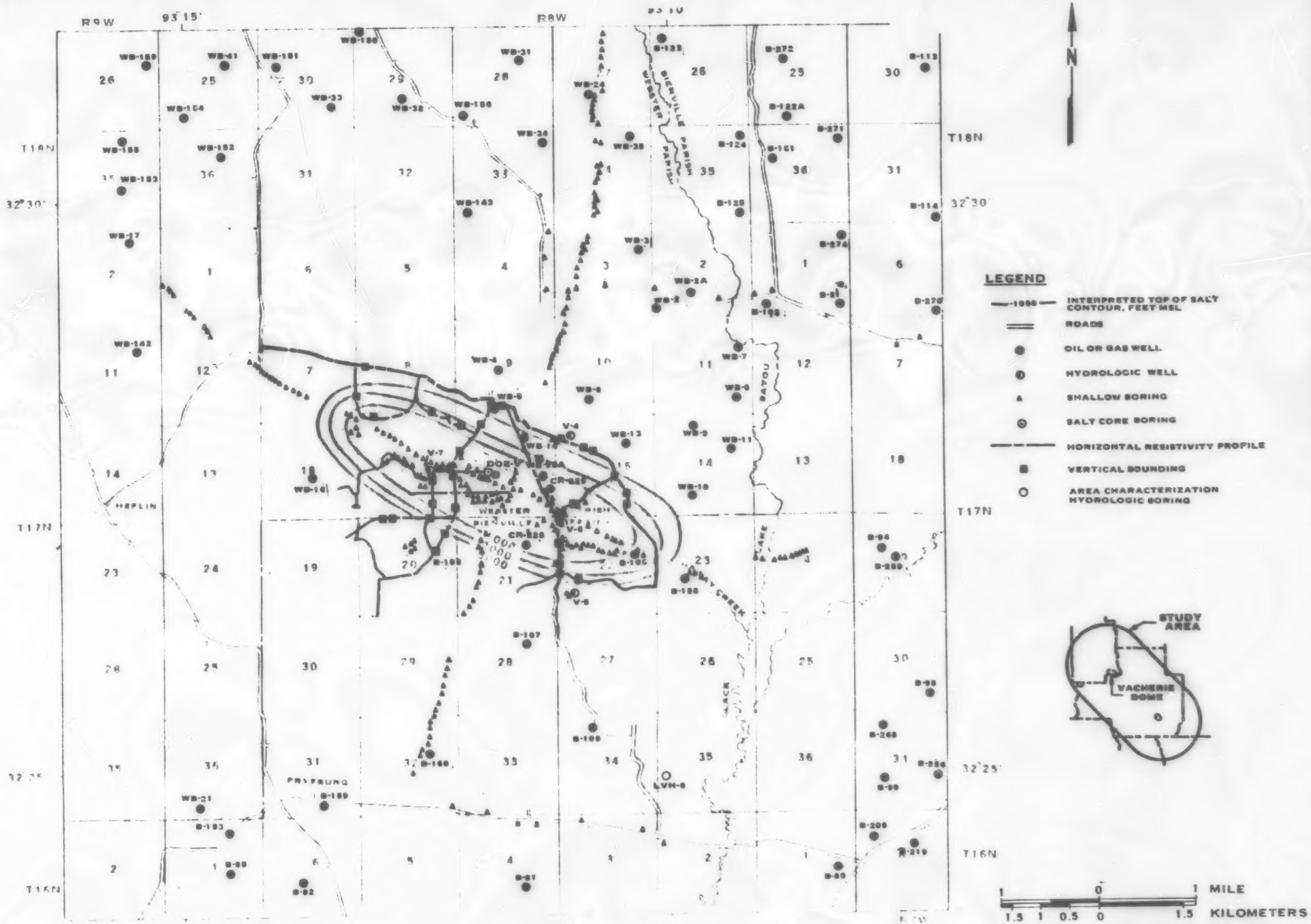
FIGURE 10-1



HYDROLOGIC AND SHALLOW BORINGS FROM MARTINEZ AND OTHERS, 1976, 1977, 1978, 1979.

WELL KEY IN APPENDIX TABLE A-4.1

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
LOCATION OF WELL AND RESISTIVITY
DATA USED IN ANALYSIS

JOB NO. MV9600 FIGURE 10-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

PREPARED ______ DATE ______
REVISED ______ DATE 12/11/80
REVISED ______ DATE ______
APPROVED GHF DATE 12/23/80

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FIGURE 10-2

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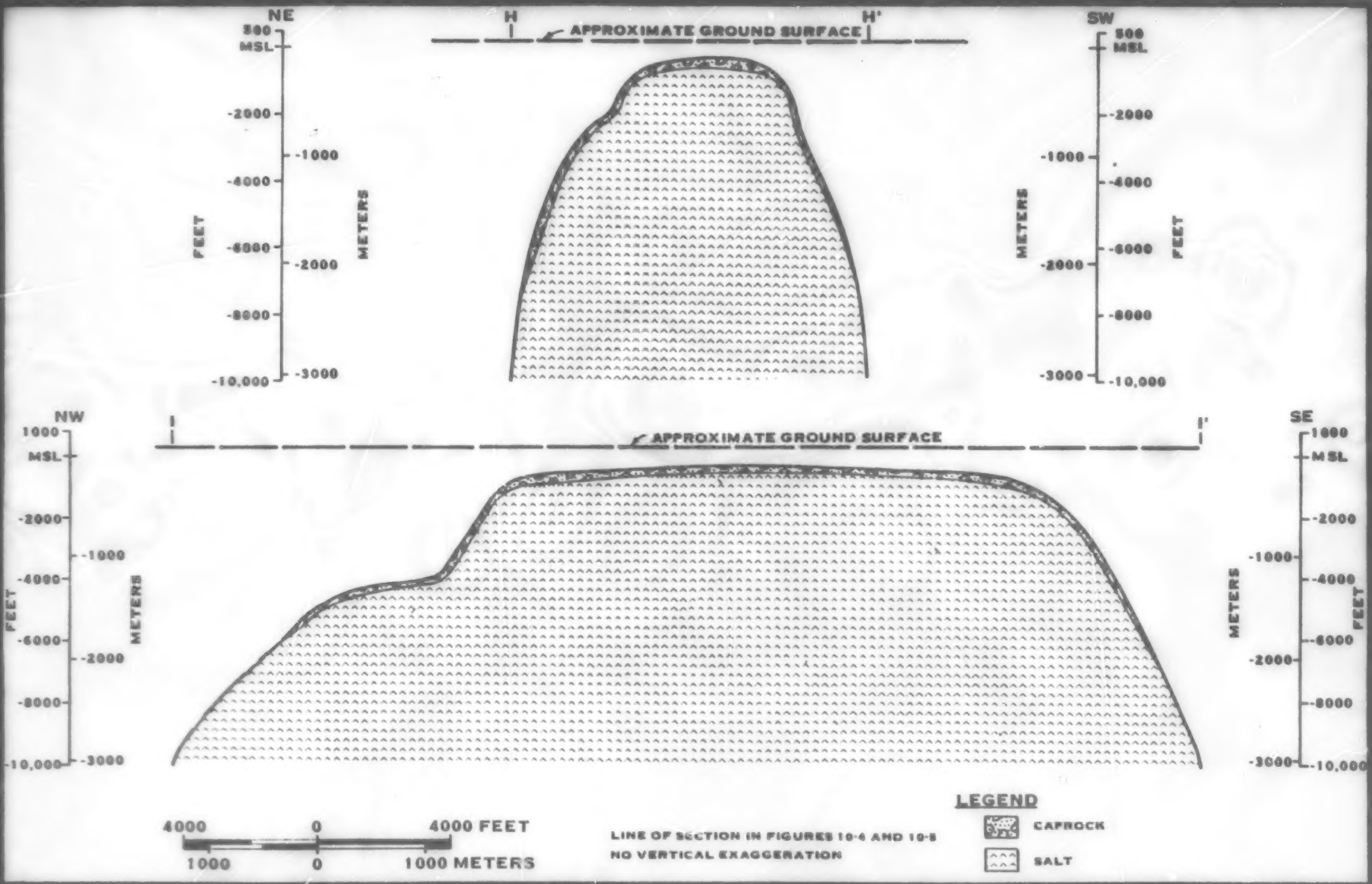


LINE OF SECTION IN FIGURES 10-4 AND 10-5
NO VERTICAL EXAGGERATION

PREPARED	TK	DATE	
REVISED		DATE	
REVISED		DATE	
APPROVED	CP	DATE	12/7/81

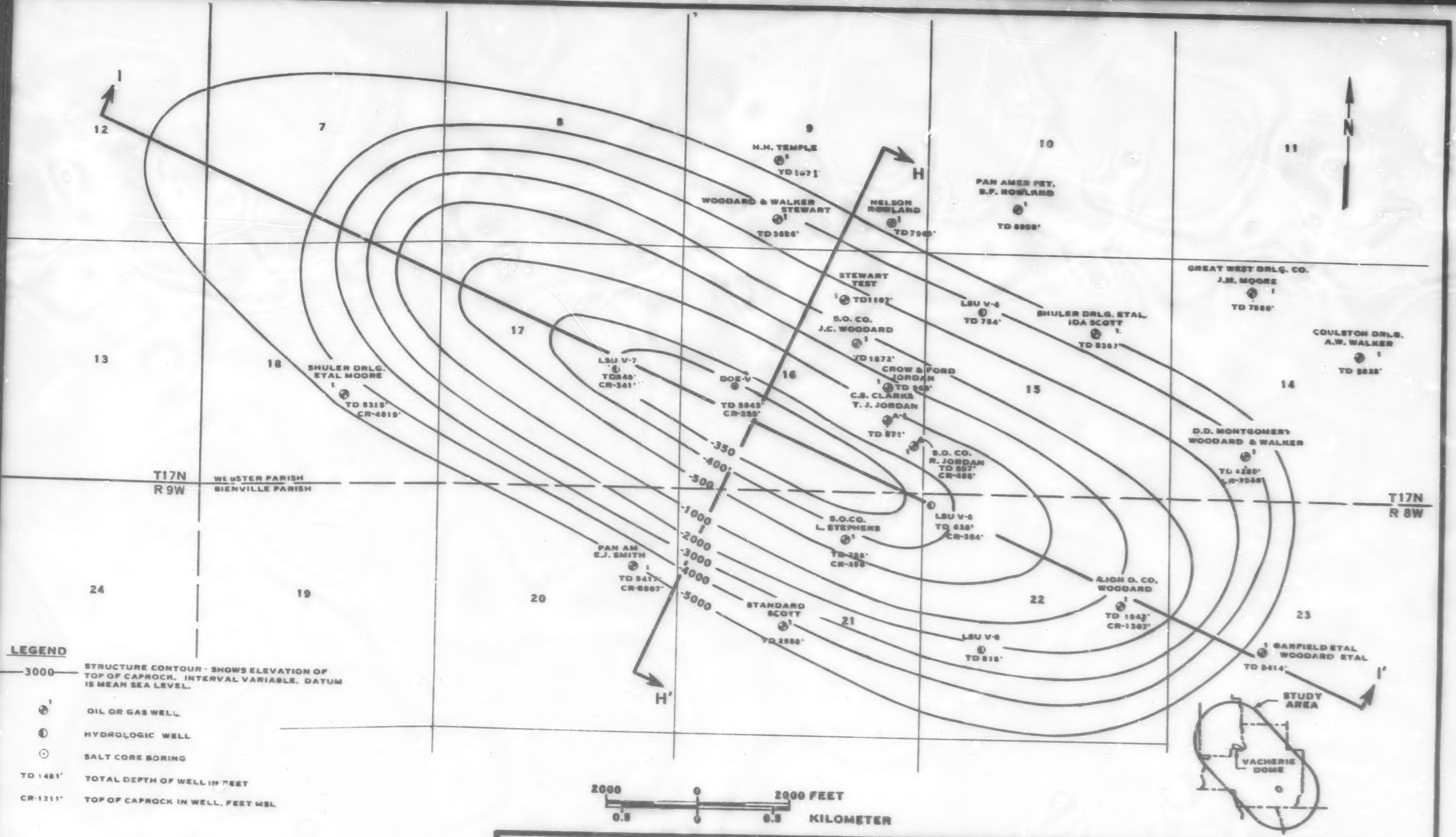
NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
GEOLOGIC SECTIONS H-H' AND I-I'

JOB NO. MV9600

FIGURE 10-3

FIGURE 10-3



PREPARED [illegible] DATE [illegible]
REVISED [illegible] DATE 12/12/80
REVISED [illegible] DATE 11/?/81
APPROVED [illegible] DATE 12/23/80

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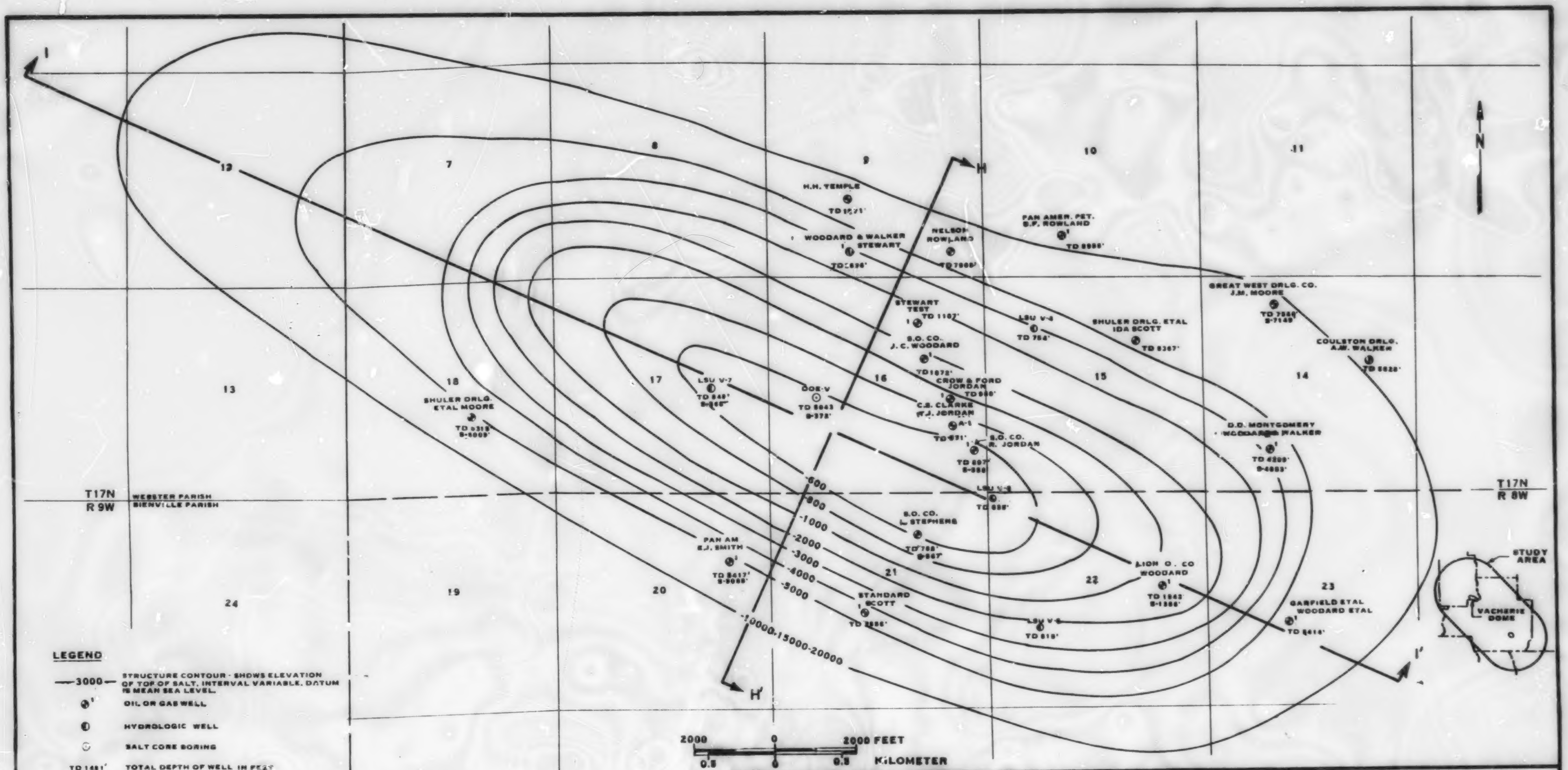
NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
STRUCTURAL CONTOUR MAP
TOP OF CAPROCK

JOB NO. MV9600

FIGURE 10-4



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REVISED		DATE	12/12/80
REVISED		DATE	11/30/81
APPROVED	GHF	DATE	12/23/80

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

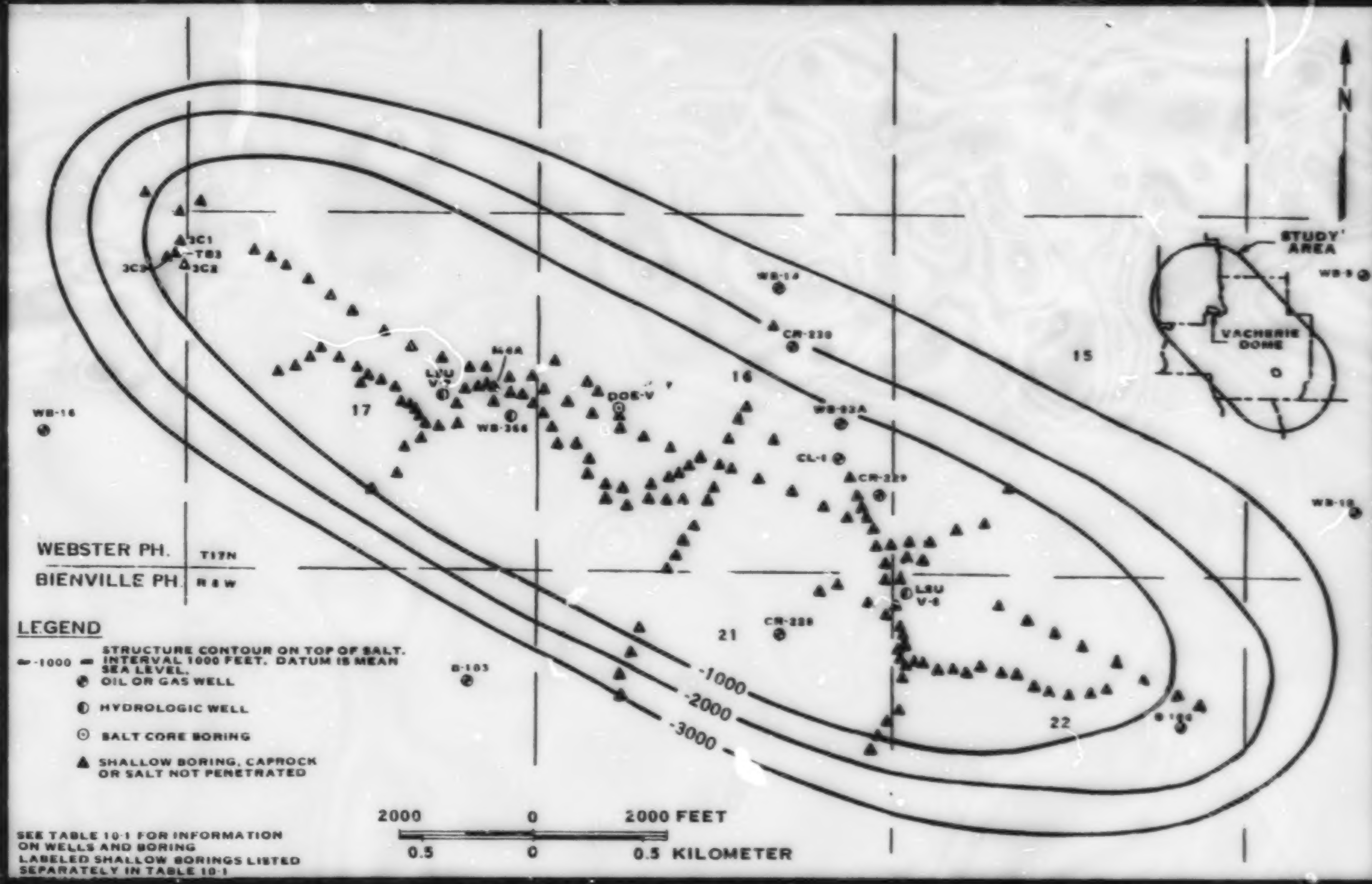
LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
STRUCTURAL CONTOUR MAP
TOP OF SALT

JOB NO. MV9600

FIGURE 10-5

FIGURE 10-6



LEGEND

-1000 STRUCTURE CONTOUR ON TOP OF SALT. INTERVAL 1000 FEET. DATUM IS MEAN SEA LEVEL.

● OIL OR GAS WELL

◐ HYDROLOGIC WELL

⊙ SALT CORE BORING

▲ SHALLOW BORING, CAPROCK OR SALT NOT PENETRATED

SEE TABLE 10-1 FOR INFORMATION ON WELLS AND BORING
LABELED SHALLOW BORINGS LISTED SEPARATELY IN TABLE 10-1

PREPARED [illegible] DATE
REVISED Jnje DATE 12/18/80
REVISED DEP DATE 1/7/81
APPROVED GHF DATE 12/23/80

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
MAP SHOWING PENETRATIONS OF DOME AND OVERBURDEN

JOB NO. MV9600 FIGURE 10-6

TABLE 10-1
BOREHOLE DATA SUMMARY
VACHERIE DOME

WELL NAME	LETCo WELL NO.	LOCATION	GROUND ELEV.* (FT.)	TOTAL DEPTH (FT.)	LOGS RUN	OUTSIDE CASING DIAM. (IN.)/ CASING DEPTH (FT.)	GROUTING	CASING SEAT DEPTH (FT.)	ABANDONMENT PROCEDURE	ELEVATION CAPROCK-TOP*/ THICKNESS (FT.)	ELEVATION SALT - TOP* / THICKNESS (FT.)	SOURCE	REMARKS
Standard #1 Jordan	CR 229	300'S, 300'W of NE/c, SE,SE Sec 16-17N-8W	227	897	Driller's Log Only	10 /206	NA	206	NA	-468 / 90	-558 / 98	Dept. of Consv. Well History Rept.	Drilled: 8/22 D & A Vacherie Dome Discovery Well
Crow & Ford #1 Jordan	WB 92A	C, NE, SE Sec 16-17N-8W	240 (est)	960	SP-Resistivity	NA	NA	NA	NA	-552/160	Salt not encountered	Geoph. Log	Drilled: /45 D & A
Standard #1 Woodard	CR 230	676' N,1358'W of SE/c, NE Sec 16-17N-8W	260 (est)	1872	Driller's Log Only	10 / 43	NA	43	NA	Caprock not encountered	Salt not encountered	Scout Card; Spooner, 1926	Drilled: 12/23-2/24 D & A
Clarke #1 Jordan	CL 1	200'S, 75'W of C, NE, SE Sec 16-17N-8W	238 (est)	571	Driller's Log Only	8 5/8 / 42	10 sx	42	NA	Caprock probably not encountered	Salt probably not encountered	Dept. of Consv. Well History Rept.	Drilled: 5/49 D & A
DOE #1 Smith	WB 14A (DOE-V)	493' SNL, 146' WEL of NE, NW, SW Sec 16-17N-8W	230	5043	Dual Lat./GR-Neut./Ind. Sph. Foc./Comp. Dens Comp. Sonic/ Fracture I D/ Cont. Direc./ Temp./Caliper	13 3/8 /297 9 5/8 /972	400 sx 800 sx	972	Open, filled w/brine. Flange well head installed	-299/272.5	-571.5 / 4227.5	Coreholes at Vacherie and Rayburns Salt Domes, L.S.U., 1978	Drilled: 4/78 Vacherie Salt Core Hole
Standard #1 Stephens	CR 228	400'N, 200'W of SE/c, NW, NE Sec 21-17N-8W	196	788	Driller's Log Only	NA	NA	NA	NA	-458/109	-567/11	Scout Card; Spooner, 1926	Drilled: /23 D & A
Lion #1 Woodard	B 106	2310'S, 990'W of NE Sec 22-17N-8W	187 (est)	1843	SP-Resistivity	9 5/8 /535	200 sx	535	Cement Plug 446'-581' w/45 sx; Cement Plug top of 9 5/8" csg w/5 sx	-1307/79	-1386/258	Dept. of Consv. Well History Rept.	Drilled: 11/52 D & A
LSU #7 Vacherie (V-7)	WB 15	C of NL, SE Sec 17-17N-8W	226 (est)	848	I. E./Comp. Sonic	5½ /796	Grouted to 794'	796	NA	-341 / 227	-568/51	Martinez et al, 1977	Drilled: 4/77 Screen set from 796' to 806'
LSU #6 Vacherie (V-6)	B 104	NW, NW Sec 22-17N-8W	219 (est)	635	I. E./Comp. Sonic	5½ /596	Grouted to 594'	596	NA	-384/27	Salt not encountered	Martinez et al, 1977	Drilled: 4/77 Screen set from 608' to 618'
LETCo Shallow Boring	M 4A	NE, NE, SW Sec 17-17N-8W	215 (est)	191	None	None	--	--	Backfilled	Caprock not encountered	Salt not encountered	LETCo Files	Drilled: 10/79
LSU Shot Hole Borings (A & B Lines)	-	-	-	75 to 100	None	None	--	--	NA	Caprock not encountered	Salt not encountered	Martinez et al, 1976	Drilled: 7/75 36 holes

NA - Not Available

* Datum is mean sea level

TABLE 10-1

BOREHOLE DATA SUMMARY

VACHERIE DOME
(CON'T)

WELL NAME	LETCo WELL NO.	LOCATION	GROUND ELEV.* (FT.)	TOTAL DEPTH (FT.)	LOGS RUN	OUTSIDE CASING DIAM. (IN.)/ CASING DEPTH (FT.)	GROUTING	CASING SEAT DEPTH (FT.)	ABANDONMENT PROCEDURE	ELEVATION CAPROCK-TOP*/ THICKNESS (FT.)	ELEVATION SALT-TOP*/ THICKNESS (FT.)	SOURCE	REMARKS
LSU Auger Borings (C & D lines)	-	-		20 to 80	Logs run in 3 holes only	None	-	-	NA	Caprock not encountered	Salt not encountered	Martinez et al, 1976	Drilled: 7/76 21 Holes
LSU Shallow Borings (S, M & B lines)	-	-	-	15 to 200	SP-Resistivity Nat. Gamma Logs run in 75% of holes	None	-	-	NA	Caprock not encountered	Salt not encountered	Martinez et al, 1977	Drilled: 5-8/77 82 holes
LETCo Shallow Borings (B line)	-	-	-	20 to 200	None	None	-	-	NA	Caprock not encountered	Salt not encountered	Martinez et al, 1978	Drilled: 5-8/78 20 holes
LSU Geotechnical Boring	TB 3	NE, NE, NE Sec 18-17N-8W	320 (est)	160'	None	NA	NA	NA	NA	Caprock not encountered	Salt not encountered	Martinez et al, 1977	Drilled: 8/77
LSU Geotechnical Borings	3C1 3C2 3C3	NE, NE, NE Sec 18-17N-8W	NA	6.5' 76' 77'	Cone Penetration	NA	NA	NA	NA	Caprock not encountered	Salt not encountered	Martinez et al, 1977	Drilled: 8/77
USGS Water Well	WB 366	NE, NE, SE Sec 17-17N-8W	250	74'	NA	NA	NA	NA	NA	Caprock not encountered	Salt not encountered	U.S.G.S. Record	Drilled: 11/76
Stewart #1 Test	WB 14	50' S. of C SE, NW, NE Sec 16-17N-8W	260 (est)	1107	SP-Resistivity	NA/20 (?)	NA	20 (?)	NA	Caprock not encountered	Salt not encountered	Geoph. Log	Drilled: 6/44
Montgomery #1 Woodard Walker	WB 10	330'S, 330'W of NE/c, SE, SW Sec 14-17N-8W	195 (est)	4289	SP-Resistivity CST CDM	NA/517	240 sx	517	NA	-3968/85	-4053/29	Geoph. Log; Dept. of Consv. Well History Rept.	Drilled: 7/57 D & A Outside -3000' Contour on top of salt
Shuler #1 Moore	WB 16	660'S, 642'E of Center Sec 18-17N-8W	275	5315	IE SL CST	8 5/8"/622	300 sx	622	Cement Plugs: 0'-27' w/10 sx 600'-648' w/15 sx 1000'-1081' w/25 sx	-4819/190	-5009/20	Geoph. Log; Dept of Consv. Well History Rept.	Drilled: 7/62-8/62 D & A Outside -3000' Contour on top of salt
Pan. Am. #1 Smith	B 103	990'W, 1650'S of NE/c Sec 20-17N-8W	313 (est)	5417	IE Microlog Dipmeter	9 5/8"/622	275 sx	527	Cement Plugs: 430'-560' w/50 sx 5257'-5417' w/50 sx	-5007/78	-5085/7	Geoph. Log; Dept of Consv. Well History Rept.	Drilled: 7/58-8/58 Outside -3000' Contour on top of salt
Great Western #1 Moore	WB 9	660' FNL, 1830' FWL of Sec 14-17N-8W	195	7580	IE Sonic	8 5/8"/2030	1100 sx	2030	Cement Plugs: 0'-45' w/10 sx 1954'-2084'/40sx	Caprock not encountered	-7169/200	Geoph. Log; Dept of Consv. Well History Rept.	Drilled: 11/61 Outside -3000' Contour on top of salt

NA - Not Available

* Datum is mean sea level

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Depth to the caprock, which was encountered in wells within the projection of the -914 meter (-3,000 ft) MSL contour to the surface, varies from 165 to 459 meters (543 to 1,506 ft) [-91 to -398 meters (-299 to -1,307 ft) MSL]. The caprock thickness varies from 24 to 83 meters (79 to 273 ft) where it has been completely penetrated. On the basis of sparse well and gravity data, the Vacherie caprock appears to cover the entire top surface of the salt body and drape the flanks to an elevation of at least -1,981 meters (-6,500 ft) MSL. It is possible that the caprock extends farther down the flanks as it does at some other domes, but no information is available to verify it.

In the Vacherie salt core hole (D.O.E. #1 Smith, et al) the depth* to the caprock is 165 meters (543 ft) [-91 meters (-299 ft) MSL]. The caprock consists of three zones of differing lithology (Nance, Rovik, and Wilcox, 1979). The uppermost carbonate zone 6 meters (21 ft) thick changes abruptly into a middle gypsum section 0.9 meter (3 ft) thick, which grades gradually into a lower anhydrite zone 76 meters (249 ft) thick. According to Taylor (1938), the three zones are normally present and are considered indicative of a well-developed caprock; less mature caprocks may have only an anhydrite zone.

The carbonate section in the Vacherie core hole extends from 165 to 172 meters (543 to 564 ft) [-91 to -98 meters (-299 to -320 ft) MSL] and contains a variety of textures and structures.

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* Unless otherwise noted, all depths given have been measured from the kelly bushing, which is usually 1.5 to 4.5 meters (5 to 15 ft) above the ground surface.

The matrix is fine-grained 0.1 to 0.5 mm (0.004 to 0.020-in) crystalline calcite. Included in this fine matrix are fragments of brecciated, micritic limestone. Fractures cut through the fine-grain matrix and are filled with coarse-grained 1 to 5 mm (0.04 to 0.20 in) sparry calcite. Porosity, resulting from open fissures and cavities, is localized. These voids have been attributed to changes in volume resulting from alteration of sulphate materials to carbonates. These cavities are lined with calcite or celestite, which varies in color from dark gray to off-white to white. Pyrite is also found in the carbonate zone.

The gypsum section is dark gray and has a fine-grain 0.2 mm (0.008 in) crystalline texture. It extends from 172 to 173 meters (564 to 567 ft) [-98 to -98.4 meters (-320 to -323 ft) MSL]. Both upper and lower contacts are gradational, but the upper contact is more abrupt. Gradation downward is in the form of interbedded gypsum and anhydrite or of isolated patches of anhydrite in gypsum.

The anhydrite section extends from 173 to 249 meters (567 to 816 ft) [-98.4 to -174 meters (-323 to -572 ft) MSL] and is light gray, grayish-brown or black, dense, and crystalline, with scattered gypsum hydration inclusions. Grain sizes range from fine 0.1 mm (0.004 in) to coarse 1 mm (0.04 in), with the boundaries between the textures sometimes occurring as very sharp and distinct contacts. Blocky inclusions occur below the 24 meters (80-ft) level measured from the top of the anhydrite zone, sometimes as fairly distinct laminated blocks, and at other times, as distorted, pillowy blocks. Although the contact between the anhydrite and salt is sharp, horizontal, and tightly cemented, a few halite crystals are found above the boundary (Nance, Rovik and Wilcox, 1979).

At LSU Hydrologic Well V-6, which was drilled into the southeastern half of the dome, the first zone of caprock was encountered at -117 meters (-384 ft) MSL and consisted of limestone, which was consistent with the three zones found in the core hole. At LSU V-7, however, which was drilled into the dome about 2.4 km (1.5 mi) to the northwest, the first caprock, encountered at -104 meters (-341 ft) MSL, consisted of dense, white to gray anhydrite. This suggests a certain degree of irregularity of zoning in the Vacherie caprock.

Depths to salt, encountered in wells within the -914-meter (-3,000-ft)-MSL contour, range from 244 to 483 meters (799 to 1,585 ft) [-170 to -422 meters (-558 to -1,386 ft) MSL]. The depth to salt is 249 meters (816 ft) [-174 meters (-572 ft) MSL] in the Vacherie salt core hole. The section of salt observed seems to indicate a fairly complicated internal composition. The beds of relatively pure halite are thin, and the anhydrite and salt layers are highly contorted, non parallel, and discontinuous. The salt core is composed of approximately 90 percent halite and 10 percent anhydrite. These layers are often isoclinally folded over distances of 0.3 to 0.6 meters (1 to 2 ft).

The gross texture of the salt core is characterized by steeply dipping bands, with isoclinal folds less than 0.6 meters (2 ft) wide oriented at 5 to 20° from the core axis (Martinez and others, 1978). Separate halite crystals in the core are typically medium-grained 6 to 25 mm (0.25 to 1.0 in), and elongated with a preferred orientation of long axes of crystals parallel to layering. Predominant in the uppermost 213 meters (700 ft) of the salt and scattered throughout the salt core, are layers of subhedral, equidimensional halite crystals, coarse-grained >25 to 51 mm (>1.0 to 2.0 in) near the salt/caprock interface. Anhydrite occurs as intragranular, disseminated inclusions in halite and as intergranular concentrations which range from discontinuous, diffuse trails to solid, internally laminated anhydrite bands or segments. Minute fluid inclusions occur in the halite and on anhydrite grain margins (Nance, Rovik and Wilcox, 1979).

Gouge or sheath zones, which are believed to form between the salt and surrounding strata during domal movement, have not been identified at Vacherie Dome. A conglomerate containing Cretaceous fossils was penetrated by an oil well on top of Vacherie Dome in the 1920's and has been interpreted to be a breccia made up of rock fragments of several formations that had been carried upward with the salt (Crowe, 1975).

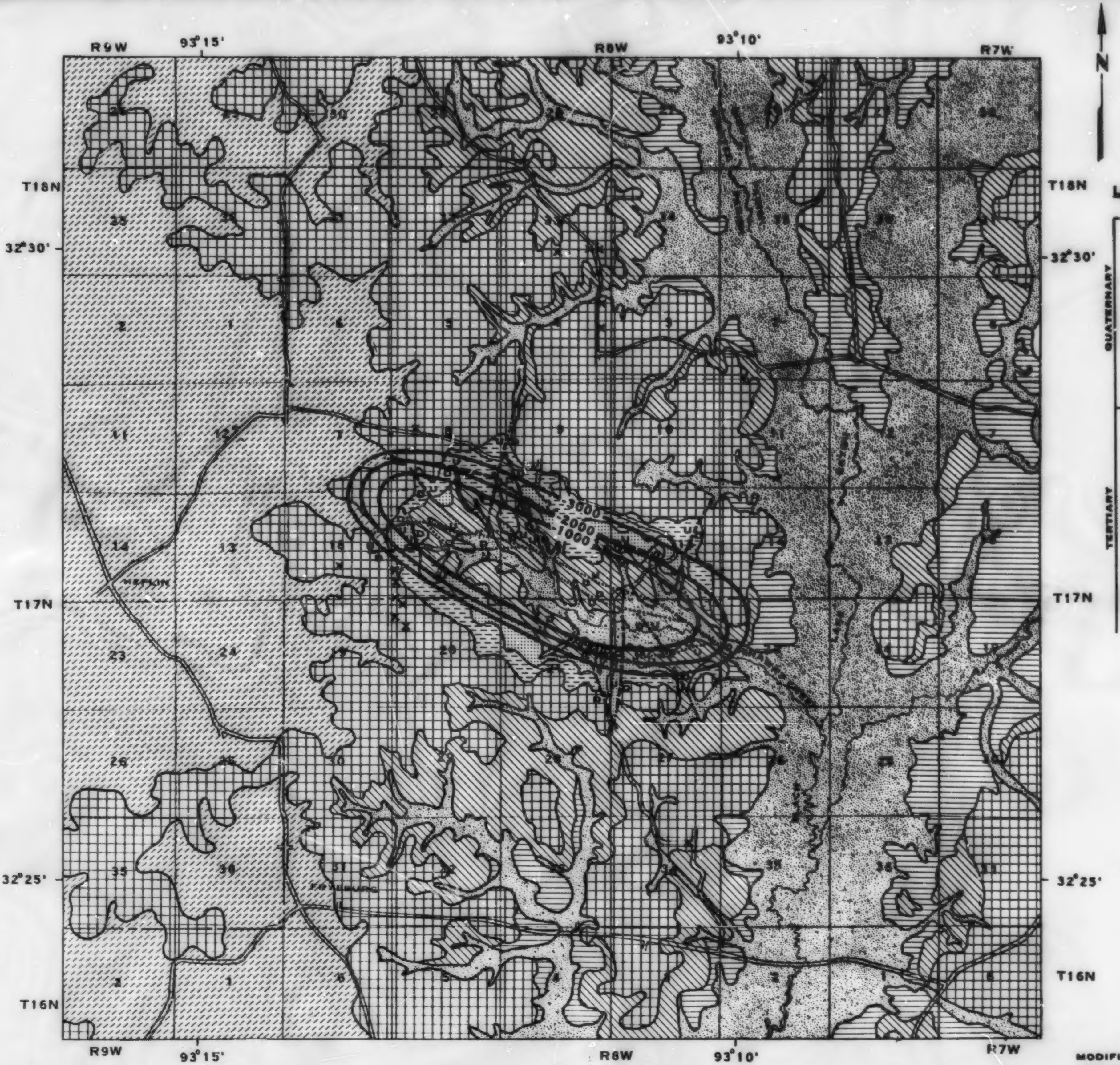
10.1.2 NEAR-DOME GEOLOGY: This section includes interpretations of surface features, stratigraphy, and structure of the strata surrounding the dome.

10.1.2.1 Surface Features: Vacherie Dome is expressed at the surface by a northwest-southeast oriented topographic low, surrounded by hills with up to 61 meters (200 ft) of relief (Figure 10-1). A small stream, Bashaway Creek, drains the central depression to the east into Black Lake Bayou, a tributary of the Red River. Spooner (1926) mentions the presence of numerous fresh water springs at the base of the hills within the depression, as well as a spring of sulfur water in the southwest quarter of section 15, T17N, R8W.

The surface above Vacherie Dome consists of Tertiary and Quaternary sediments. The upper Eocene Sparta Formation, normally exposed in the area, forms a resistant ridge that partially encircles the central depression above the dome; Cane River and Wilcox inliers form concentric rings within the depression (Figure 10-7). Gravelly Pleistocene and Holocene (Recent) deposits cover the floor of the central depression and flank most stream valleys in the area.

The Quaternary deposits west of the dome are mapped as a single unit. These deposits are related to Red River alluviation to the west (Martin and others, 1954) with some locally derived modern alluvium along stream valleys.

Dominantly sandy deposits over most of the hilly upland area around Vacherie, which Martin and others (1954) mapped as Quaternary terrace, are here interpreted as belonging to the Sparta Formation. In many places the Sparta sands are overlain by fluvial deposits containing chert gravel which is noticeably coarser than that in the topographically lower and younger terrace deposits. These upland gravels are probably lag deposits, remnants of a once continuous blanket of Pliocene and Pleistocene



LEGEND

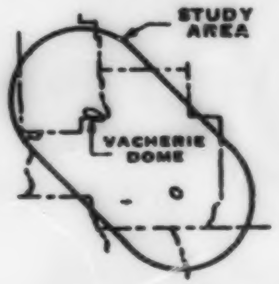
QUATERNARY	PLEISTOCENE AND RECENT		▨	ALLUVIUM AND LOWER TERRACE DEPOSITS
			▤	INTERMEDIATE TERRACE DEPOSITS
			▨	UPPER TERRACE DEPOSITS
			▨	RED RIVER TERRACE DEPOSITS AND RECENT ALLUVIUM (UNDIFFERENTIATED)
TERTIARY	PLIOCENE		X	UPLAND FLUVIAL DEPOSITS
	EOCENE	CLAIBORNE	▦	SPARTA FORMATION
			▤	CANE RIVER FORMATION
	PALEOCENE	WILCOX	▨	WILCOX GROUP (UNDIFFERENTIATED)

U/D — FAULT - UPTHROWN/DOWNTHROWN, DASHED WHERE INFERRED

U/D ····· COVERED FAULT

—-1000— STRUCTURE CONTOUR OF TOP OF SALT. INTERVAL 1000 FEET. DATUM IS MEAN SEA LEVEL.

—— ROAD



1 0 1 MILE

1.5 1 0.5 0 1.5 KILOMETERS

MODIFIED FROM MARTINEZ AND OTHERS, 1976.

BASE FROM U.S. GEOLOGICAL SURVEY 1:62,500 QUADRANGLES.

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
SURFACE GEOLOGY MAP

JOB NO. MV9700 FIGURE 10-7

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED Myc DATE ______
REVISED ______ DATE ______
REVISED ______ DATE ______
APPROVED DGP DATE 11/30/81

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FIGURE 10-7

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terrace deposits which was extensively eroded, the finer, reworked products from which have been since incorporated into younger and less extensive terrace and colluvium deposits.

The Sparta Formation at Vacherie Dome is composed of weathered, red-brown sand and silty sand with occasional clay stringers. The Cane River Formation consists of a lower unit of weathered, gray-green, glauconitic silty clay with occasional thin, brown, clay-ironstone ledges overlain by an upper unit of chocolate-brown clay (Martin and others, 1954). The contact between the upper and lower units is a clay-ironstone layer. The sediments of the Wilcox Group exposed at Vacherie Dome consist of weathered, reddish brown, thin-bedded and cross-bedded, micaceous sands, sandy silts, and silts containing ironstone concretions and fossil wood (Martin and others, 1954). Quaternary deposits, consisting of sand and gravel that characteristically contain chert pebbles, generally grade upward to fine-grain sand, silt, and clay. The older and topographically higher Quaternary deposits are primarily sand and gravel, the overlying finer-grained sediments having been eroded.

On the basis of surface elevations and subsurface interpretation of data from shallow cored borings, Kolb (1979) recognizes three Quaternary terrace levels flanking Bashaway Creek above Vacherie Dome. (See Volume I for a discussion of the formation of the Quaternary terraces.) He tentatively correlates the lowest terrace (0.6 to 0.9 meters (2 to 3 ft) above Bashaway Creek flood plain) with the Deweyville Terrace; the middle terrace (6 to 8 meters (20 to 25 ft) above the flood plain) with the Prairie or some younger terrace; and the highest terrace (9 to 12 meters (30 to 40 ft) above the flood plain) with the Prairie or Montgomery Terrace. Kolb (1979) determined average gradients for the low and high terraces of 1.3 m/km (7 ft/mi) and 1.7 m/km (9 ft/mi), respectively. He considers the upland area that flanks the Bashaway Creek drainage basin to be Sparta Formation, occasionally overlain by gravels of the Bentley or Williana Terraces.

Martin and others (1954), on the other hand, recognize only the Prairie Terrace within the central depression, and mapped the upland area as Bentley and Montgomery Terraces.

Terrace levels of different ages may also be recognized on the basis of soil profiles. Under similar conditions of climate, topography, and parent material, older terraces would ordinarily be expected to exhibit thicker and better developed soil profiles. A soil survey conducted over portions of Vacherie Dome detected at least two different ages of soils (i.e., two terrace levels) developed in the Pleistocene deposits (Martinez and others, 1977).

The LSU/IES map (Martinez and others, 1979) of terrace deposits along Black Lake Bayou and its tributaries was checked in the field and against a topographic base map with a 1.5 meters (5 ft) contour interval and was modified in part. The modifications primarily involved combining a low-level terrace with Recent alluvium for mapping purposes. This terrace level is generally less than 1.5 meters (5 ft) above the modern floodplain and is probably subject to flooding, thus appearing to be related to local alluviation. In addition, some minor changes were made in the location of formation contacts.

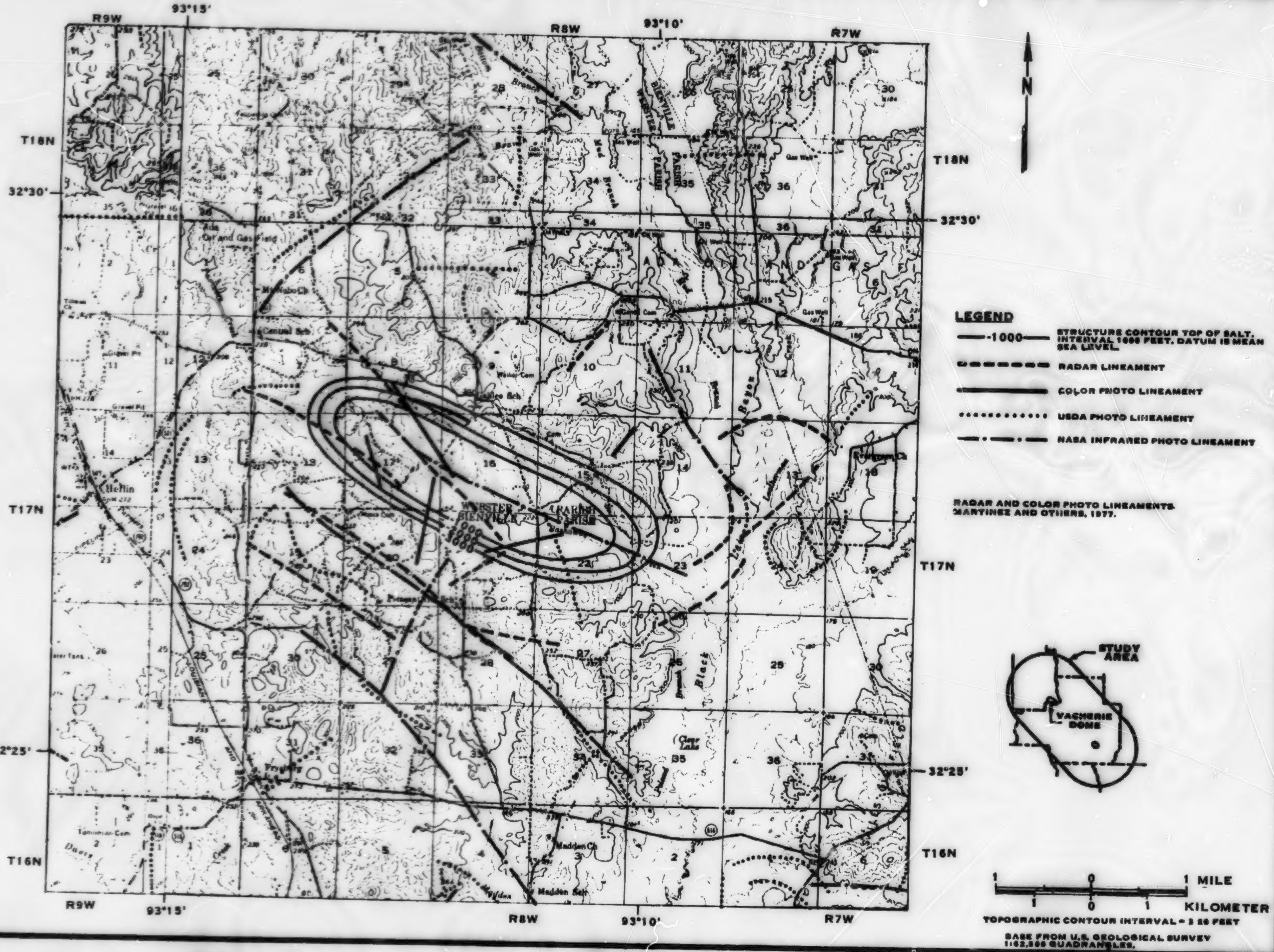
The main purpose of identifying, correlating, and mapping Quaternary stream terraces is to provide information from which to interpret domal stability during the Quaternary. Comparison of terrace surface elevations along Bashaway Creek to those along similar streams adjacent to the dome, but not affected by domal movement, has been used by Kolb (1978, 1979) to try to detect domal movement that may have occurred after the terraces were deposited. Domal movement could produce either abnormally high or low terrace elevations above the dome. Irregularity in the terrace profile or gradient may also be indicative of uplift or subsidence caused by domal instability. No abnormal terrace elevations or irregular terrace profiles have been recognized above Vacherie Dome (Martinez and others, 1979).

Thickening of Quaternary deposits over the western part of the dome suggests that subsidence may have occurred in that area, possibly as a consequence of domal movement or salt dissolution during the Quaternary (Martinez and others, 1978). Arcuate lineaments in Quaternary deposits along Black Lake Bayou east of Vacherie Dome (Figure 10-8) may also indicate domal movement during the past 300,000 to 500,000 years; but, the relation of these lineaments to domal movement is speculative. (See section 10.1.2.3 for a discussion of lineaments at Vacherie Dome.)

10.1.2.2 Stratigraphy: The following section discusses the lithologies of stratigraphic units at Vacherie Dome from the base of the Rusk Formation of the Trinity Stage/Group to the Quaternary alluvium. Lithologic interpretations of some of the deeper units are based on geophysical log characteristics. Lithologies of the Upper Cretaceous units above the base of the Austin Group and of the Tertiary units were determined from descriptions of cuttings from LSU Hydrologic Wells V-6 and V-7, and from LETCo's Area Characterization Boring LVH-6. For some units, no near-dome lithologic information was available. In such cases, reference is made to Section 9.2.2 for the general lithologic description typical of the unit throughout the study area.

10.1.2.2.1 Cretaceous System, Comanchean Series-

10.1.2.2.1.1 Trinity Stage/Group: No lithologic information is available for the Mooringsport member of the Rusk Formation near Vacherie Dome. In general, the unit is more clastic in the Minden Basin than in the Winnfield Basin, where it is characterized by thick carbonates and interbedded shales. The Greenwood member at Vacherie Dome is composed of predominantly fine sand, silt, and shale in wells drilled to date. The member does not contain the thin gray limestones described elsewhere in Bienville Parish by Echols (1965). It is possible that in the vicinity of Vacherie Dome, the limestones were eroded at the unconformity on top of the Comanchean Series. The Greenwood member, like the Mooringsport member, is more clastic in the Minden Basin than in the Winnfield Basin.


R9W
93°15'
R8W
93°10'
R7W
T18N
32°30'
T17N
32°25'
T16N
N
WEBSTER PARISH
BIENVILLE PARISH
Black Bayou
Clear Lake
Madden Ch
Madden Sch
Heflin
LEGEND
-1000
STRUCTURE CONTOUR TOP OF SALT. INTERVAL 1000 FEET. DATUM IS MEAN SEA LEVEL.
RADAR LINEAMENT
COLOR PHOTO LINEAMENT
USDA PHOTO LINEAMENT
NASA INFRARED PHOTO LINEAMENT
RADAR AND COLOR PHOTO LINEAMENTS MARTINEZ AND OTHERS, 1977.
STUDY AREA
VACHERIE DOME
1 0 1 MILE
1 0 1 KILOMETER
TOPOGRAPHIC CONTOUR INTERVAL – 20 FEET
BASE FROM U.S. GEOLOGICAL SURVEY 1:62,500 QUADRANGLES.

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
LINEAMENT MAP

JOB NO. MV9600 FIGURE 10-8

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED DATE 12-3-80
REVISED DATE 12/18/80
REVISED DATE 1/30/81
APPROVED GHF DATE 12/23/80

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FIGURE 10-8

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10.1.2.2.1.2 Fredericksburg Stage/Group: Due to the lack of wells of appropriate depth, information about the lithologies of the Paluxy and Goodland Formations is not available for the Vacherie Dome area. Refer to Section 9.2.2 for the study area lithologic description.

10.1.2.2.1.3 Washita Stage/Group: The only lithologic description available for the Washita Stage/Group at Vacherie Dome is from Spooner (1926). He stated that the Washita is composed of a fossiliferous conglomerate made up of well-rounded red, blue, green, and gray limestone pebbles, smoky quartz pebbles, and chert pebbles. The matrix is a fine-grain, angular quartz sand and green argillaceous material, cemented by calcite. Minor amounts of shale (gumbo), sand, and limestone are also present. In general, the undifferentiated Washita at Vacherie is more coarse-grained and more fossiliferous than elsewhere in the study area, possibly indicative of shoaling over a topographic high caused by uplift of the salt mass.

10.1.2.2.2 Cretaceous System, Gulfian Series-

10.1.2.2.2.1 Woodbine Stage/Tuscaloosa Group: Lithologic descriptions of the Tuscaloosa Group at Vacherie Dome indicate no significant differences in lithology from that of the general study area. The section consists of dark shales and silty sands, with a well-developed basal sand, which is consistent with descriptions elsewhere in the study area.

10.1.2.2.2.2 Eagle Ford Stage/Group: The Eagle Ford Formation at Vacherie Dome consists of dark gray, silty shales with thin lenses of sandstone. The calcium carbonate content seems to be lower here than elsewhere in the study area. The marls and calcareous sand described by Echols (1965) elsewhere in Bienville Parish are absent in the Vacherie area, possibly because the seas were deeper during Eagle Ford deposition due to rim syncline development.

10.1.2.2.2.3 Austin Stage/Group: The Tokio Formation at Vacherie is composed of soft to indurated, micaceous claystones containing traces of pyrite, chalcopyrite, disseminated carbonaceous matter, and lignite fragments. The base of the formation contains interbedded light gray, microcrystalline, argillaceous, fossiliferous limestone; whereas, elsewhere in the study area the basal strata are chalky, and the upper part of the formation contains sands.

The Brownstown Formation at Vacherie Dome contains interbedded sands, sandstones, and marlstones. The sands vary from colorless to light gray, olive, and brown, and they contain small amounts of glauconite and pyrite. The sandstones vary from light gray to yellowish-gray and grayish-brown, are calcareous, and contain interbedded calcareous siltstones, and sandy, silty limestones. The marlstones are light to medium gray, fossiliferous, micaceous, and locally silty. The near-dome lithology contrasts with the study area lithology in that the Brownstown at Vacherie is slightly more calcareous and fossiliferous than elsewhere, indicating a shallower environment of deposition.

10.1.2.2.2.4 Taylor Stage/Group: The Ozan Formation at Vacherie is composed of light to medium gray, chalky, silty, marlstone. Toward the top of the formation it contains interbedded light gray, glauconitic, chalcopyritic, medium-coarse siltstone and silty limestone. The lithology of the Ozan at Vacherie does not vary greatly from the silty, sandy marls and thin shales of the study area, except for interbedded limestones.

The Annona Formation at Vacherie Dome is composed of white to light gray to pale yellow chalk in which are inclusions of sparry calcite, quartz, fossils, pyrite, chalcopyrite, and argillaceous and carbonaceous matter. Locally, the chalk grades laterally into marlstone. The thin, interbedded, micaceous shales typical of the study area are not found here, possibly because of a shallow-water, high-agitation environment.

The lithology of the Marlbrook Formation at Vacherie Dome is a light gray, chalky marlstone, with traces of pyrite, quartz, and fossils. It is locally silty. The lithology at Vacherie does not differ in any appreciable way from the rest of the study area.

10.1.2.2.2.5 Navarro Stage/Group: The Saratoga Formation at Vacherie is composed of a light gray to white chalk, which contains embedded fossils, sparry calcite, quartz sand, and clay minerals. The chalk in the upper part of the formation is silty and grades into a light gray to yellowish-gray, calcareous siltstone. Locally the chalk grades laterally into a light gray marlstone. The Saratoga is less glauconitic at Vacherie than elsewhere in the study area.

The base of the Nacatoch Formation at Vacherie is composed of a gray to yellowish-gray, calcareous siltstone, which contains bedded chalk, sparry calcite, and fossils. In the middle of the formation, the siltstones grade upward into light gray sands which contain silt and varying amounts of calcareous cement. This cement has locally consolidated the sands into sandstones. Toward the top of the Nacatoch the sands grade upward into calcareous siltstones of the same type described at the base of the formation. Glauconite, pyrite, and mica are found throughout the formation. The Nacatoch Formation at Vacherie is not as calcareous as elsewhere throughout the region because the typical basal chalk is absent. The argillaceous component is also less at Vacherie, possibly indicating a deepening of the water around Vacherie during the deposition of the formation.

The Arkadelphia Formation at Vacherie Dome grades upward from a chalky, light gray, or white marlstone to a pale yellow, cryptocrystalline to micro crystalline limestone and chalk mixture. The formation is very fossiliferous and contains interbedded thin sandstones. The near-dome Arkadelphia appears to be more calcareous and less argillaceous than elsewhere in the study area, perhaps indicating deposition on a topographic high.

[redacted]

10.1.2.2.3 Tertiary System, Paleocene and Eocene Series-

10.1.2.2.3.1 Midway Stage/Group: The lithology of the Midway at Vacherie grades upward from a light gray to white marlstone at the base, to a medium to light gray, silty, micaceous claystone. It is silicified locally and very hard. The typical Midway of the study area is much darker in color, lignitic, carbonaceous, and fossiliferous, indicating that at Vacherie deposition was in a shallower, nonreducing environment.

10.1.2.2.3.2 Wilcox Stage/Group: The Wilcox at Vacherie is composed of light gray to brownish-gray, silty claystone, which grades upward into an argillaceous, sandy siltstone, with interbeds of lignite and colorless to gray, brown, and red sands. Glauconite and pyrite are disseminated throughout the unit and form local accumulations. The Wilcox at Vacherie does not seem to vary greatly from the Wilcox typical of the study area.

10.1.2.2.3.3 Claiborne Stage/Group: On the basis of interpreted data from drill cuttings and geophysical logs of Area Characterization Boring LVH-6, the Carrizo Formation is not recognized at Vacherie Dome.

The Cane River Formation at Vacherie Dome grades upward from a brownish-gray to medium gray claystone, to a pale yellowish-brown to light gray marlstone. Although both units are glauconitic and locally silicified, the marlstone is more glauconitic and very fossiliferous. The change in lithology from claystone to marlstone is caused by an increased calcium carbonate content. The Cane River typical of the study area is somewhat more pyritic than at Vacherie.

The lithology of the Sparta Formation at Vacherie consists of light gray to pale orange sands with thin beds of lignite toward the bottom of the formation associated with brownish-black, silty claystone. Since the Sparta is exposed over much of the area around Vacherie, varying amounts of the top of the formation have been eroded. For this reason the upper silt and clay unit is thinner here than elsewhere in the study area.

The Cook Mountain and Cockfield Formations are not present at Vacherie Dome due either to erosion or to nondeposition.

10.1.2.2.4 Quaternary System - Lithologies of the Quaternary terraces and alluvium at Vacherie Dome are similar to study area lithologies as described in Section 9.2.2, and elaborated on in section 10.1.2.1. In general, the terraces consist of fluvial deposits of gravel, sand, silt, and clay, with the gravel generally at the base, grading into finest materials at the top. The Quaternary alluvium consists of interbedded sands, silts, and clays.

10.1.2.3 Structure: Vacherie Dome is located in the Vacherie Subbasin of the Minden Basin (Figure 9-7). Five structural highs, which are connected by saddles, surround the subbasin: the Lake Bistineau Arch to the south and southwest, Sailes Arch to the southeast, West Bryceland High to the east, Ada Arch to the northeast, and Sibley Arch to the northwest (Figure 9-7). These arches are well defined by subsurface control from oil and gas wells drilled on the structures. Well control within the Vacherie Subbasin, however, is considerably less, especially on the west side of Vacherie Dome (Figure 10-2).

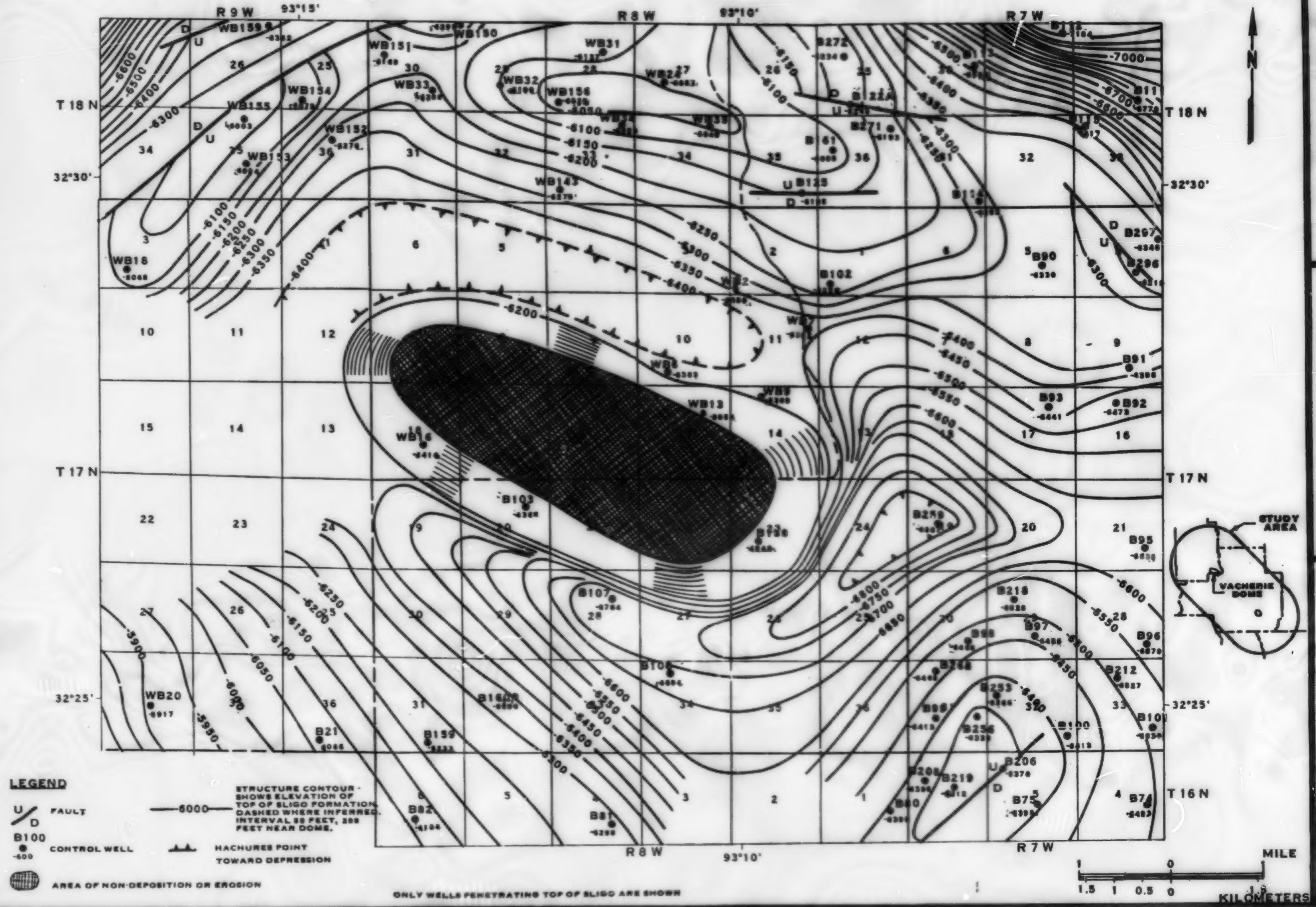
The salt withdrawal basin for Vacherie Dome is approximately 18 km (11 mi) long and 10 km (6 mi) wide with the long axis oriented northwest-southeast (Crowe, 1975). The beds on the flanks of the surrounding highs dip into the Vacherie Subbasin, averaging from 3 degrees on the Lower Cretaceous, Sligo Formation (Figure 10-9) to 0.5 degree on the base of the Upper Cretaceous, Annona Formation (Figure 10-10) (Crowe, 1975).

Basinward thickening of the sedimentary layers varies from lesser rates in the eastern and southern Vacherie Subbasin to greater rates in the western and northern subbasin. Within the eastern subbasin the greatest change in thickness occurs in the Rodessa, James, and Pine Island Formations (lower Trinity) (Figure 10-11), whereas in the western subbasin the greatest change occurs in the Pine Island and Sligo Formations (Crowe, 1975). Seismic data indicate that even greater thickening may occur in the older Hosston Formation and Cotton Valley Group, at least on the north side of Vacherie Dome (Crowe, 1975). None of the oil wells in the basin penetrated these two units. Thickening basinward decreases above lower Trinity units as shown by isopachous contour maps of the Ferry Lake Formation (Figure 10-12) and the Paleocene Midway Group (Figure 10-13).

The main areas of thickening are in the rim synclines that surround Vacherie Dome. The synclines are most prominent on the southeast and northwest flanks of the dome as shown by the Lower Cretaceous structural contour maps (Figures 10-9 and 10-14). The structural interpretations of Upper Cretaceous and Tertiary formations (Figure 10-10, 10-15, and 10-16) indicate that the synclines decreased in size and migrated toward the northern flank of Vacherie Dome through time. Studies of rim synclinal development by Kupfer (1977) conclude that salt movements from the synclines into the dome were greatest during the Late Jurassic and the Early Cretaceous and, although movements decreased with time, they continued at least through early Tertiary time.

Dips of the sedimentary layers on the flanks of Vacherie Dome also indicate that the most active domal growth took place during the Late Jurassic and Early Cretaceous. The intruded salt has upwarped Cretaceous and Tertiary formations for a distance of 914 meters (3,000 ft) outward from the edge of the salt pillar, resulting in dips as steep as 30 to 35 degrees on the top of the Sligo Formation (Crowe, 1975) (Figures 10-17 and 10-18). (Locations of the geologic sections are shown in Figure 10-19. Dips gradually decrease toward the top of the Lower Cretaceous section and are substantially reduced in the Upper Cretaceous and Tertiary section.

Missing as well as thinned stratigraphic sections on the flanks of Vacherie Dome, in the Sligo, Pine Island, James, and Rodessa Formations (Figures 10-17 and 10-18), support the interpretation that extensive domal growth occurred during the Early



LEGEND

U/D FAULT

B100 -600 CONTROL WELL

—6000— STRUCTURE CONTOUR - SHOWS ELEVATION OF TOP OF SLIGO FORMATION. DASHED WHERE INFERRED. INTERVAL 50 FEET, 200 FEET NEAR DOME.

HACHURES POINT TOWARD DEPRESSION

AREA OF NON-DEPOSITION OR EROSION

ONLY WELLS PENETRATING TOP OF SLIGO ARE SHOWN

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
STRUCTURAL CONTOUR MAP
TOP OF SLIGO FORMATION

JOB NO. MV9600

FIGURE 10-9

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED ______ DATE 6/2/80
REVISED ______ DATE 12/18/80
REVISED ______ DATE 11/3/81
APPROVED GHE DATE 12/23/80

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FIGURE 10-9

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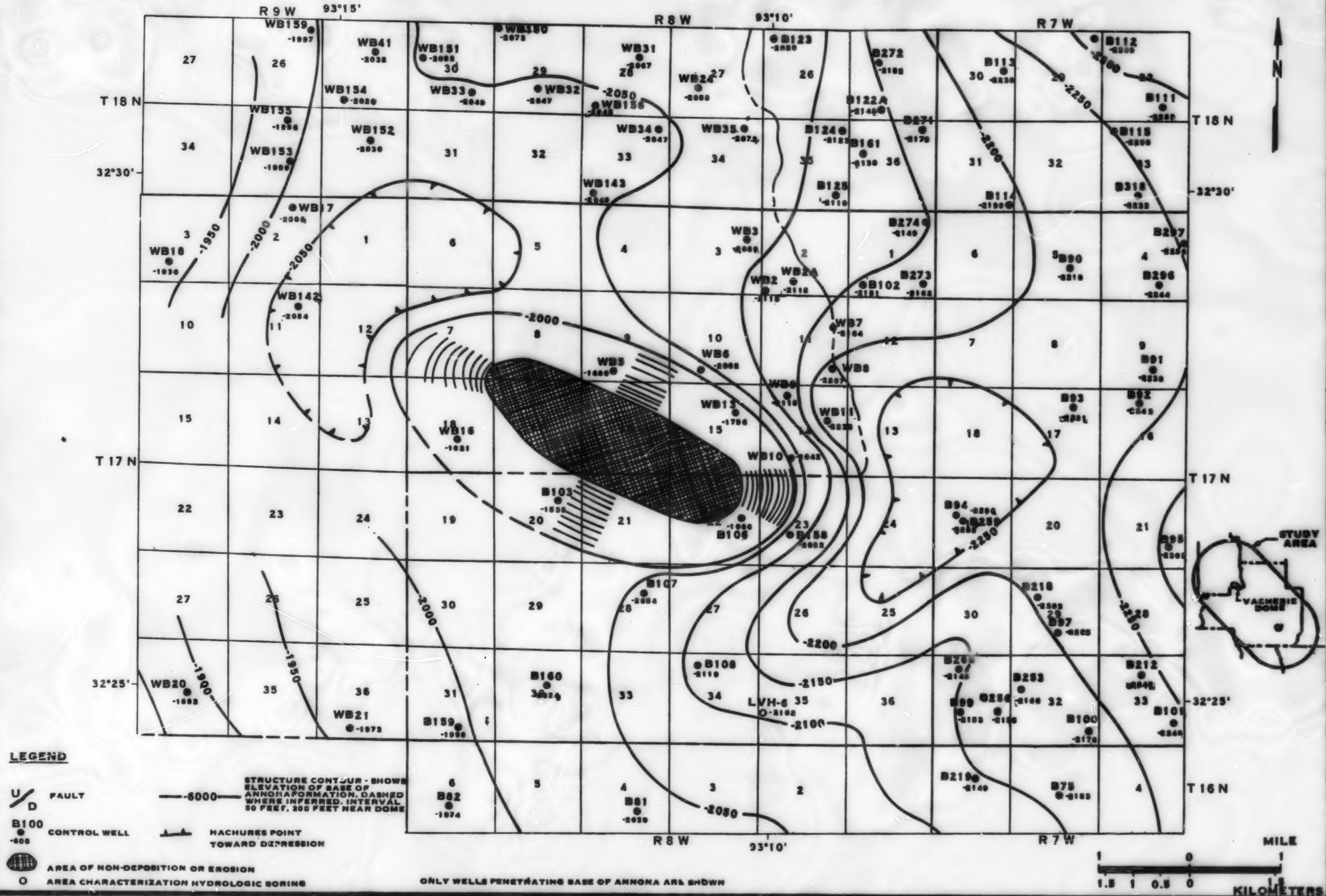

LEGEND

U/D FAULT

—-6000— STRUCTURE CONTOUR - SHOWS ELEVATION OF BASE OF ANNONA FORMATION. DASHED WHERE INFERRED. INTERVAL 50 FEET, 200 FEET NEAR DOME

B100 ● -600 CONTROL WELL

HACHURES POINT TOWARD DEPRESSION

▨ AREA OF NON-DEPOSITION OR EROSION

○ AREA CHARACTERIZATION HYDROLOGIC BORING

ONLY WELLS PENETRATING BASE OF ANNONA ARE SHOWN

NORTH LOUISIANA STUDY AREA
VACHERIE DOME

STRUCTURAL CONTOUR MAP
BASE OF ANNONA FORMATION

JOB NO. MV9600

FIGURE 10-10

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED DATE 6/30/80
REVISED DATE [illegible]
REVISED DATE 11/30/80
APPROVED GHF DATE 12/23/80

T-1371-2

FIGURE 10-10

BEST DOCUMENT AVAILABLE

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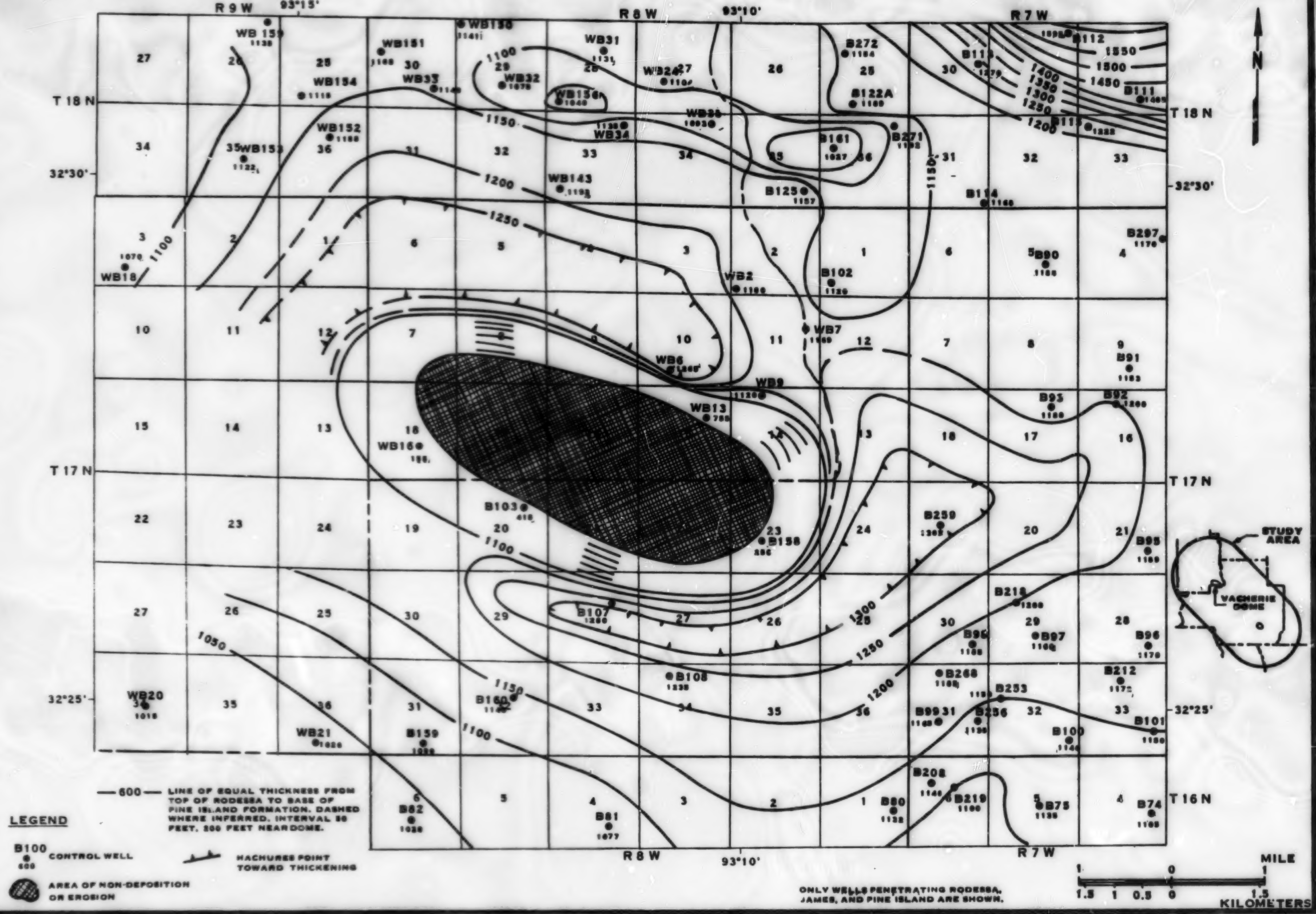

R 9 W
93°15'
R 8 W
93°10'
R 7 W
T 18 N
T 17 N
T 16 N
32°30'
32°25'
N
1550
1500
1450
1400
1350
1300
1250
1200
1150
1100
1050
STUDY AREA
VACHERIE DOME
MILE
1.5 1 0.5 0 1
KILOMETERS
1.5 1 0.5 0 1.5
LEGEND
—600— LINE OF EQUAL THICKNESS FROM TOP OF RODESSA TO BASE OF PINE ISLAND FORMATION. DASHED WHERE INFERRED. INTERVAL 50 FEET, 200 FEET NEAR DOME.
B100 600 CONTROL WELL
HACHURES POINT TOWARD THICKENING
AREA OF NON-DEPOSITION OR EROSION

ONLY WELLS PENETRATING RODESSA, JAMES, AND PINE ISLAND ARE SHOWN.

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
ISOPACHOUS CONTOUR MAP OF
RODESSA, JAMES, AND
PINE ISLAND

JOB NO. MV9600 FIGURE 10-11

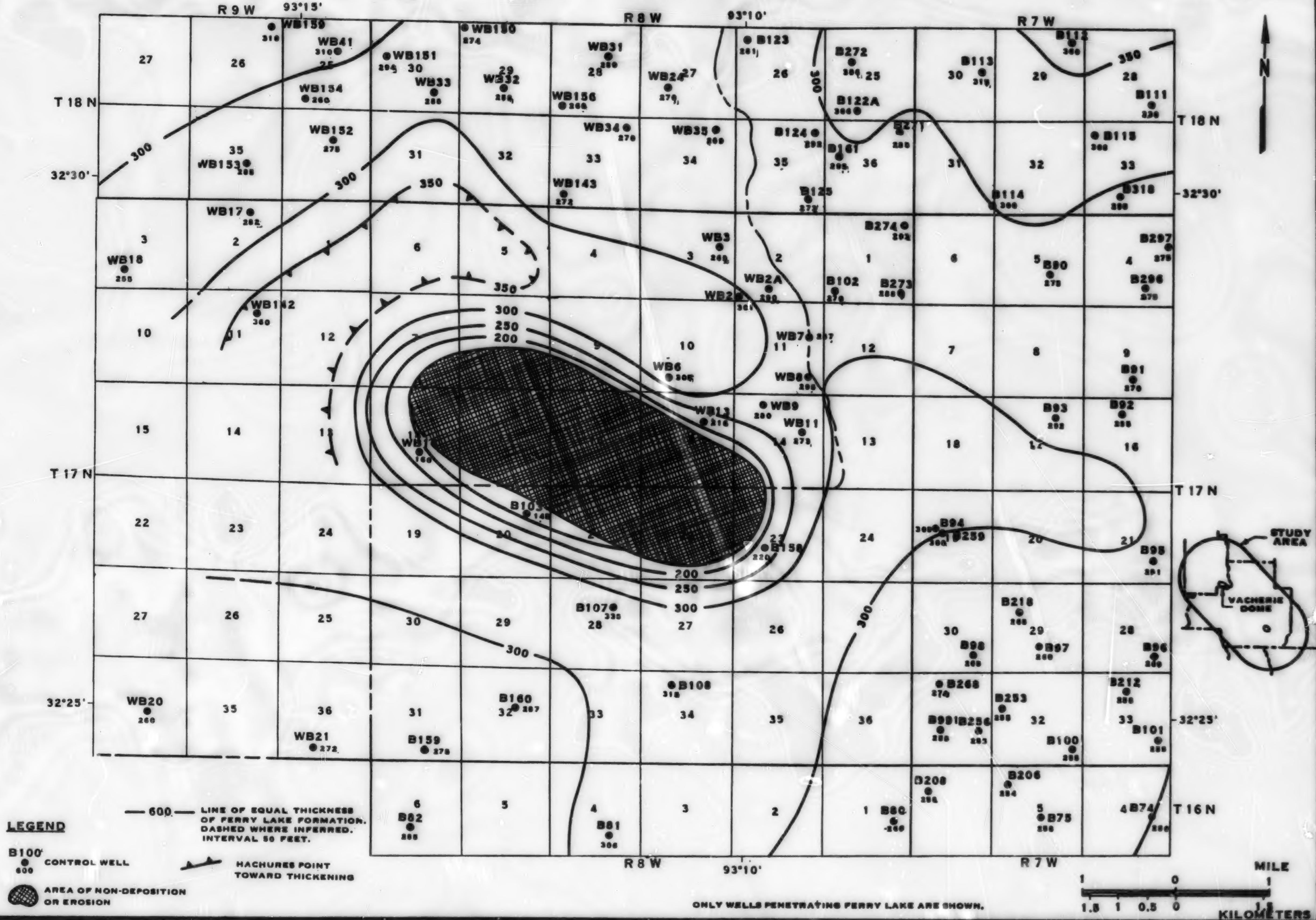
NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED ERMP DATE 6/20/80
REVISED Gmf DATE 12/15/80
REVISED Dw DATE 1/30/81
APPROVED GHF DATE 12/23/80

T-1372-2

FIGURE 10-11



ONLY WELLS PENETRATING FERRY LAKE ARE SHOWN.

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
ISOPACHOUS MAP OF
FERRY LAKE FORMATION

JOB NO. MV9600 FIGURE 10-12

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

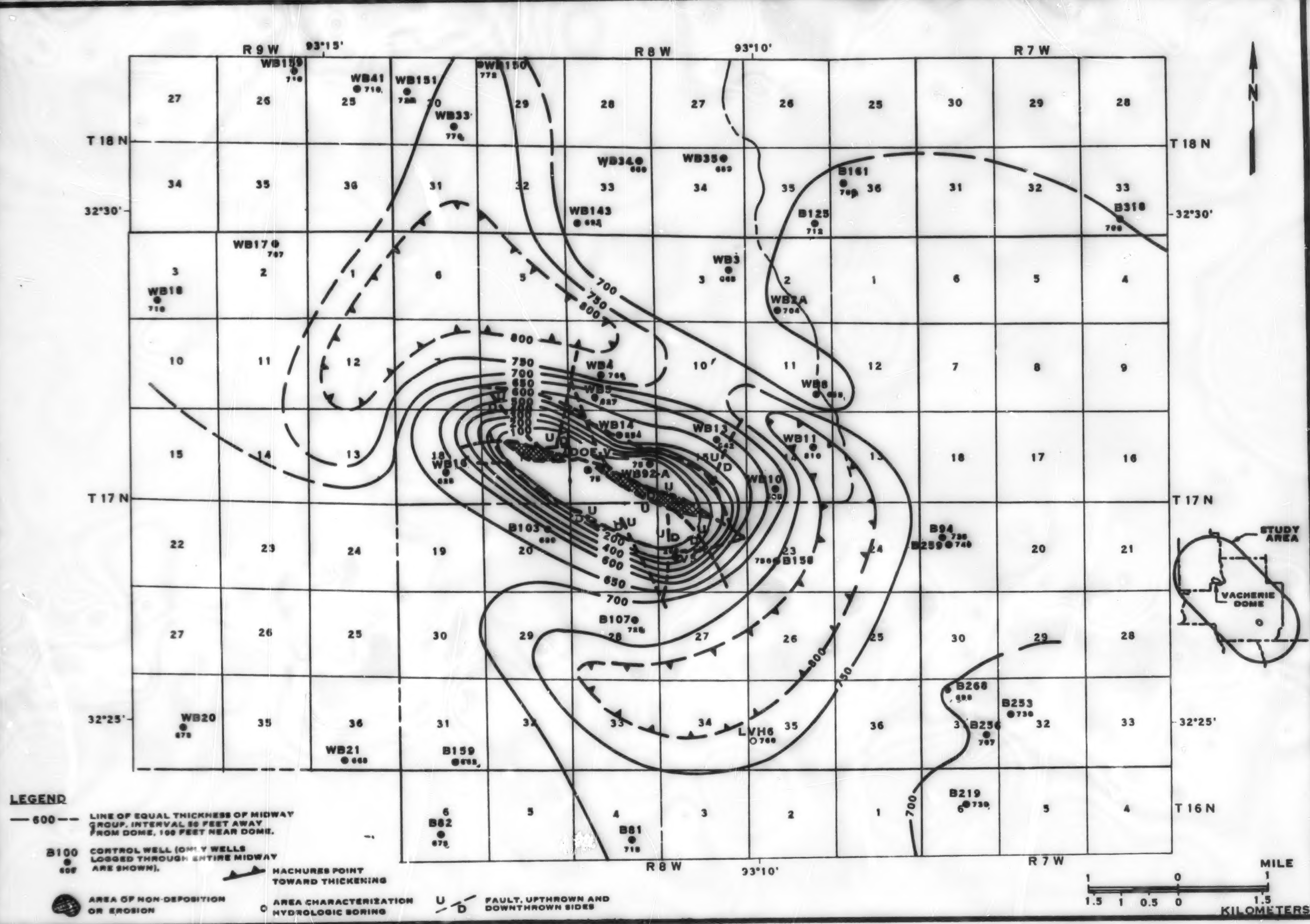
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED		DATE	6/30/80
REVISED		DATE	12/18/80
REVISED		DATE	11/30/81
APPROVED	GHF	DATE	12/23/80

T-1373-2

FIGURE 10-12

BEST DOCUMENT AVAILABLE 149



NORTH LOUISIANA STUDY AREA
VACHERIE DOME
ISOPACHOUS CONTOUR MAP
OF MIDWAY GROUP

JOB NO. MV9600

FIGURE 10-13

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED DATE
REVISED DATE 12/10/80
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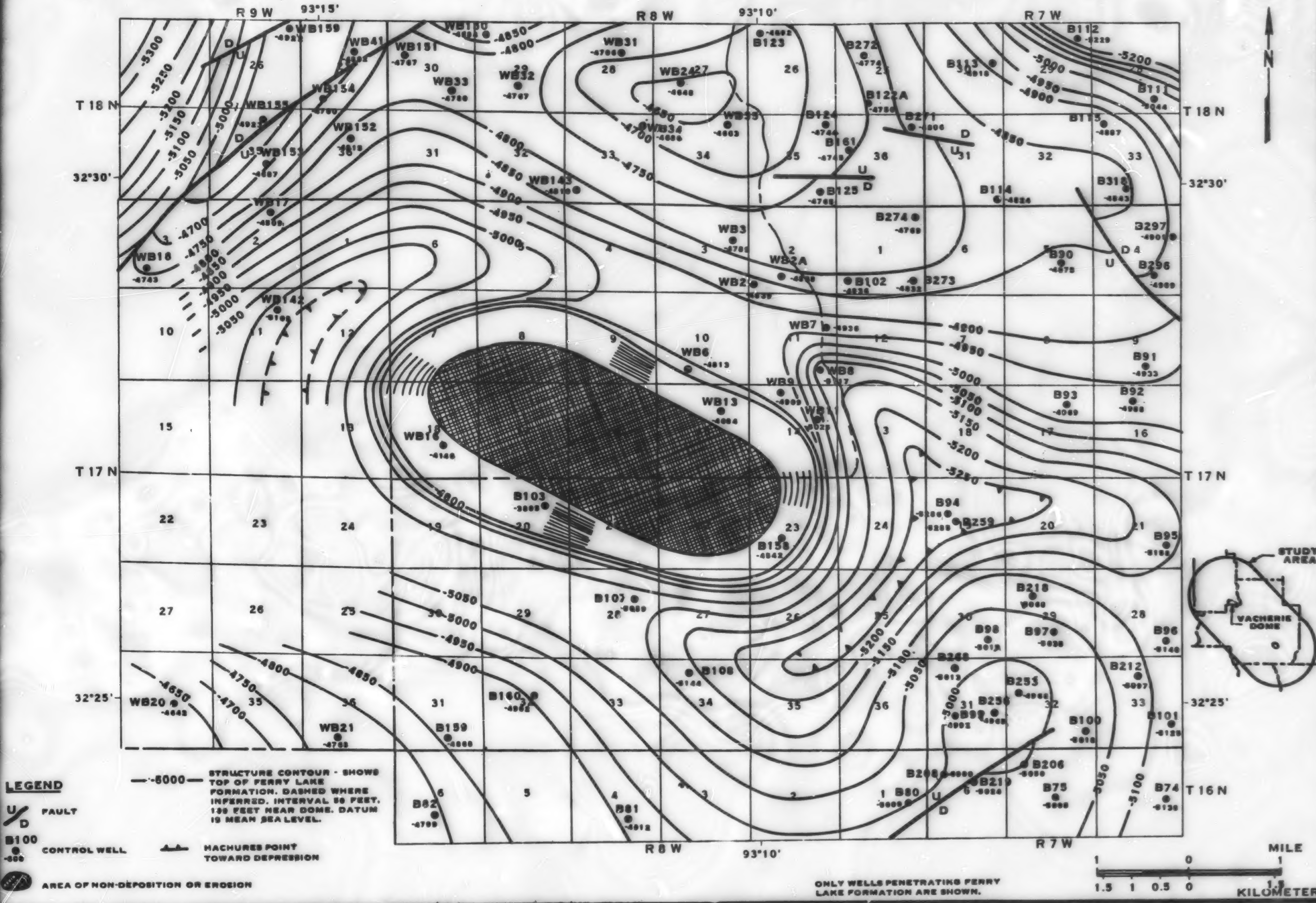
T-1374-2

FIGURE 10-13

BEST DOCUMENT AVAILABLE

150



LEGEND

—-5000— STRUCTURE CONTOUR - SHOWS TOP OF FERRY LAKE FORMATION. DASHED WHERE INFERRED. INTERVAL 50 FEET. 130 FEET NEAR DOME. DATUM IS MEAN SEA LEVEL.

U/D FAULT

B100 ● -000 CONTROL WELL

HACHURES POINT TOWARD DEPRESSION

AREA OF NON-DEPOSITION OR EROSION

ONLY WELLS PENETRATING FERRY LAKE FORMATION ARE SHOWN.

NORTH LOUISIANA STUDY AREA

VACHERIE DOME

STRUCTURAL CONTOUR MAP
TOP OF FERRY LAKE FORMATION

JOB NO. MV9600

FIGURE 10-14

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

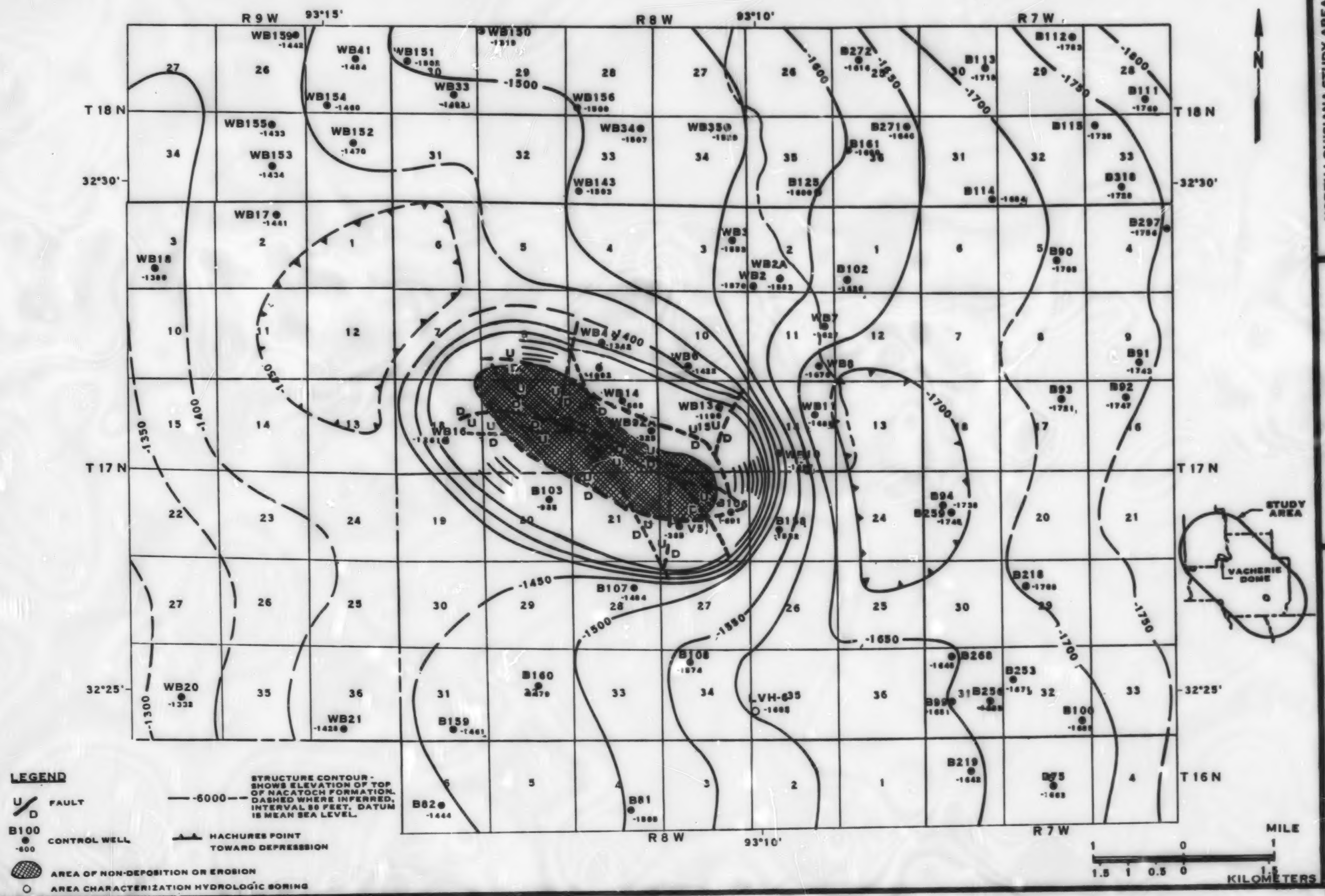
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED TJK DATE 1/30/80
REVISED DATE 1/28/80
REVISED DATE 11/30/81
APPROVED GHF DATE 12/23/80

T-1375-1

FIGURE 10-14

BEST DOCUMENT AVAILABLE



NORTH LOUISIANA STUDY AREA

VACHERIE DOME
STRUCTURAL CONTOUR MAP
TOP OF NACATOCH FORMATION

JOB NO. MV9600 FIGURE 10-15

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

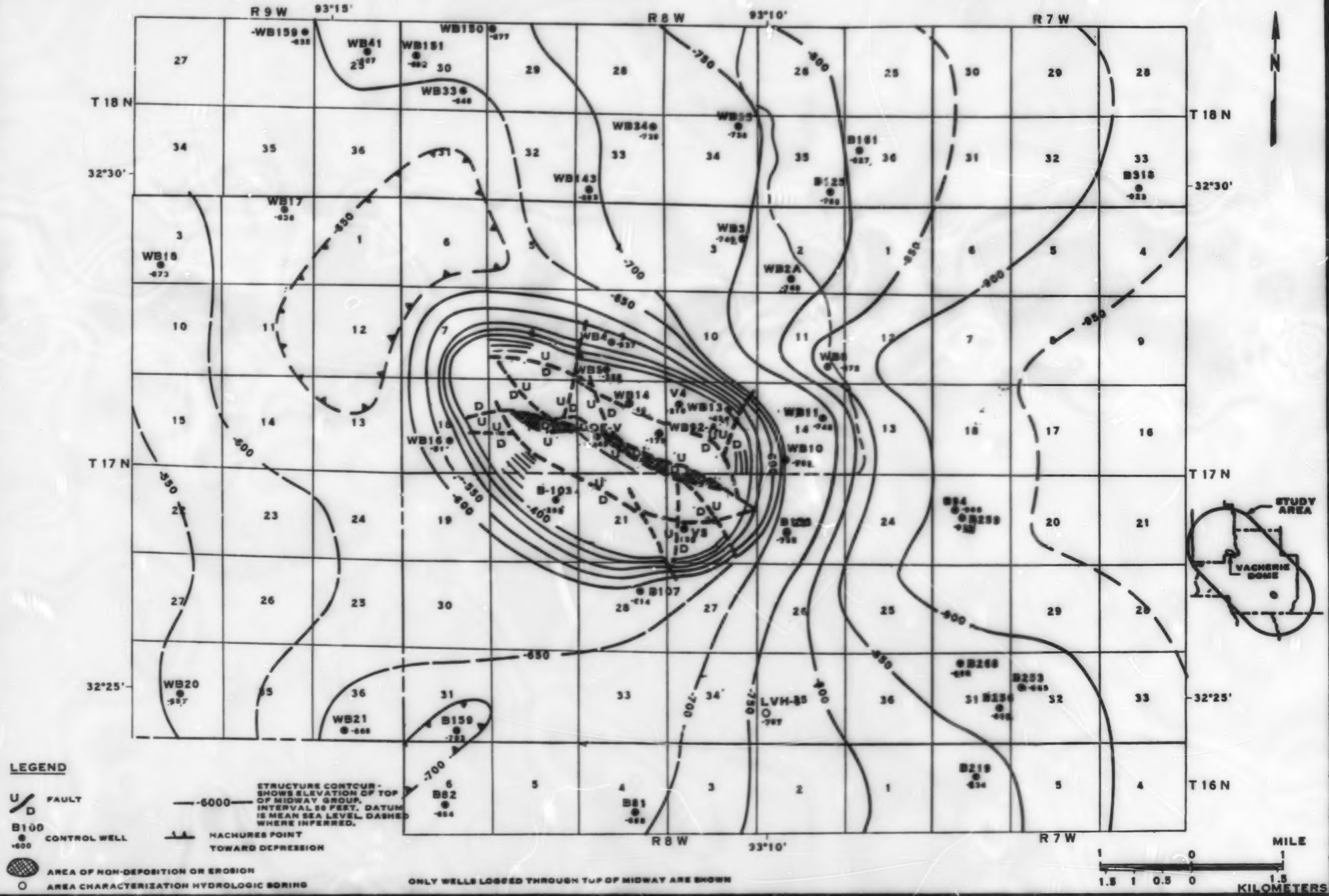
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED [illegible] DATE [illegible]
REVISED [illegible] DATE 12/18/80
REVISED DJ DATE 1/20/81
APPROVED GHF DATE 12/23/80

T-1376-1

FIGURE 10-15

BEST DOCUMENT AVAILABLE 152



NORTH LOUISIANA STUDY AREA
VACHERIE DOME
STRUCTURAL CONTOUR MAP
TOP OF MIDWAY GROUP

JOB NO. MV9600
FIGURE 10-16

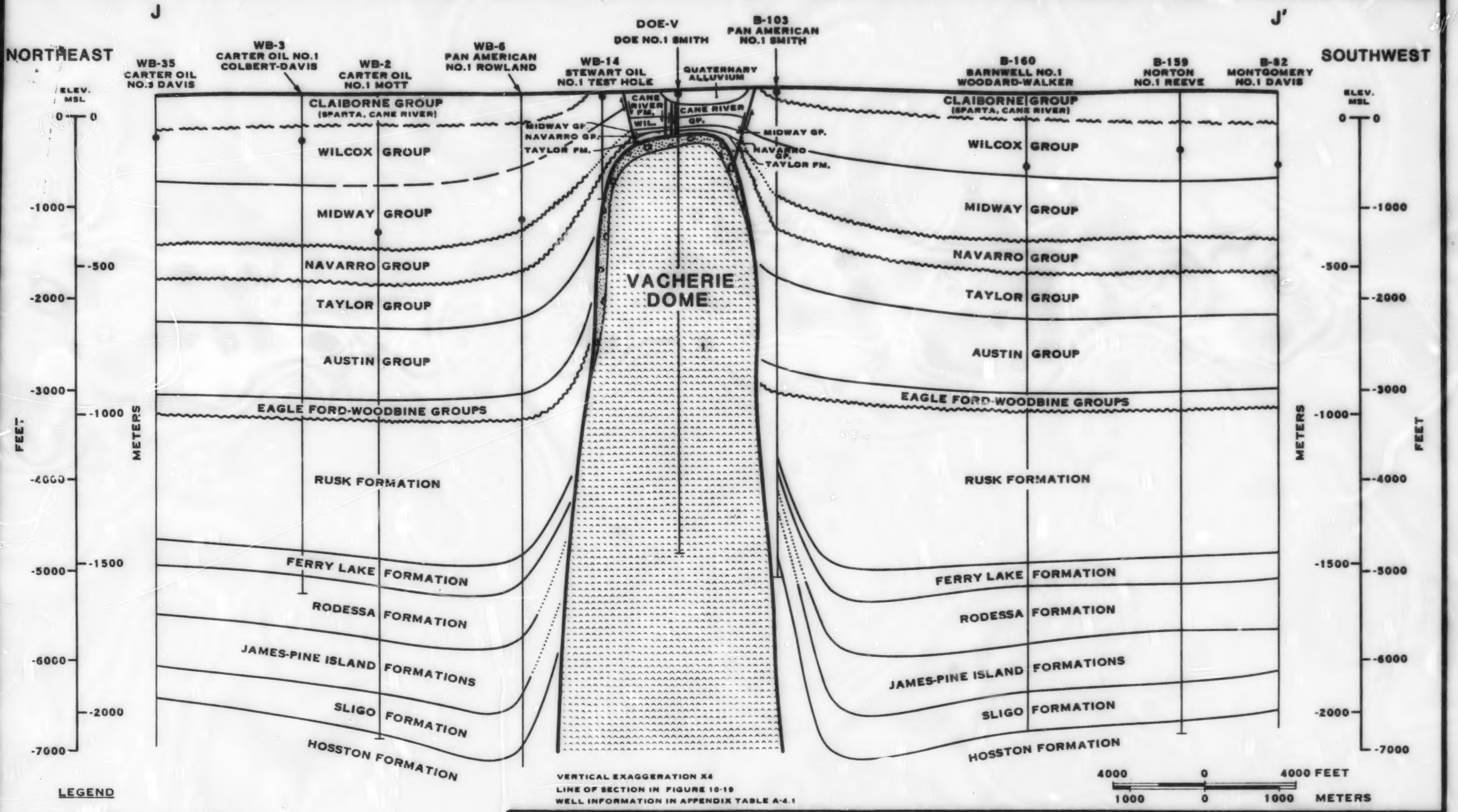
NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED DATE 12/30/80
REVISED DATE 12/18/80
REVISED DATE 1/13/81
APPROVED GHE DATE 12/23/80

T-1377-2

FIGURE 10-16



VERTICAL EXAGGERATION X4
LINE OF SECTION IN FIGURE 10-19
WELL INFORMATION IN APPENDIX TABLE A-4.1

LEGEND

- ● TOP OF LOGGED INTERVAL
- ⫽ FAULT
- ⋯⋯ LOCAL UNCONFORMITY
- 〰〰 REGIONAL UNCONFORMITY

PREPARED ______ DATE ______
REVISED ______ DATE ______
REVISED ______ DATE ______
APPROVED ______ DATE 1/30/81

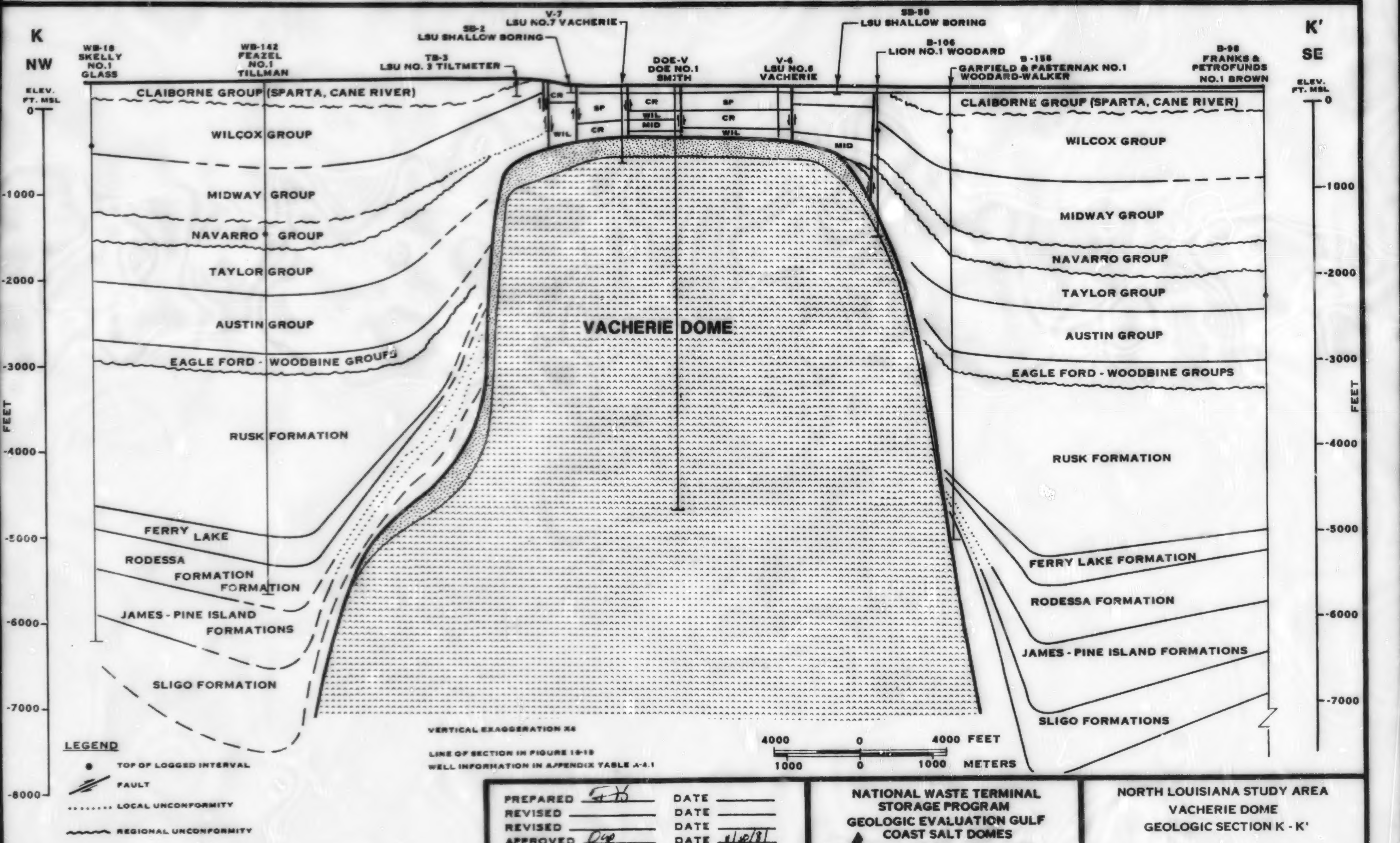
T-1054-3

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
GEOLOGIC SECTION J - J'

JOB NO. MV9600

FIGURE 10-17



PREPARED Ft Ks DATE
REVISED DATE
REVISED DATE
APPROVED Dup DATE 1/20/81

T-1055-3

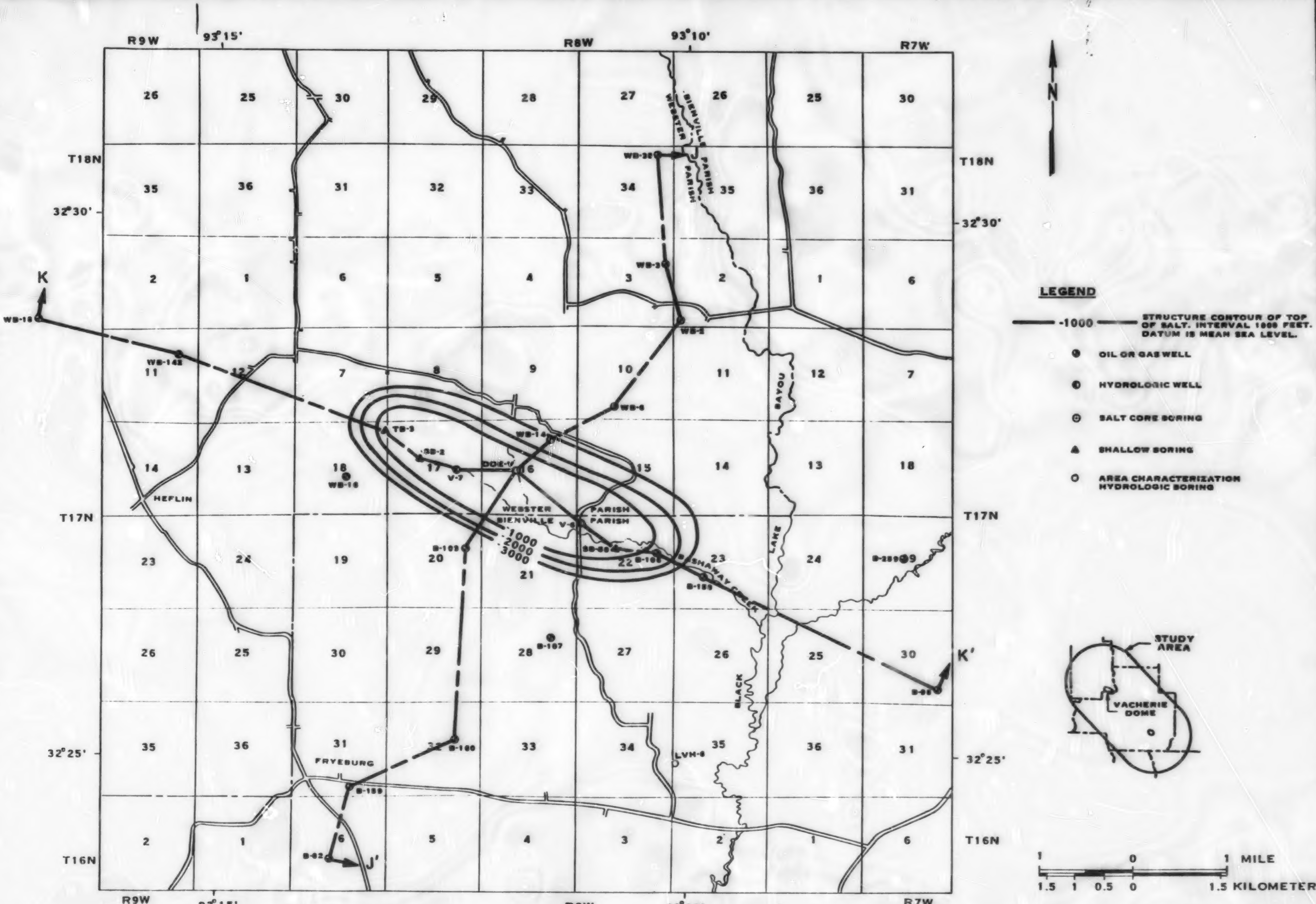
NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA
VACHERIE DOME
GEOLOGIC SECTION K - K'

JOB NO. MV9600

FIGURE 10-18



NORTH LOUISIANA STUDY AREA
VACHERIE DOME
LOCATION OF GEOLOGIC SECTIONS
J-J' AND K-K'

JOB NO. MV9600

FIGURE 10-19

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED MKL DATE 6/30/80
REVISED DATE 12/18/80
REVISED DATE 11/30/81
APPROVED GHF DATE 12/23/80

T-1378-2

FIGURE 10-19

BEST DOCUMENT AVAILABLE

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Cretaceous. Sections are missing in three wells: Shuler Drilling #1 Moore (WB-16), Pan American Petroleum #1 Smith (B-103), and Garfield and Pasternak #1 Woodard Walker (B-158) (Figure 10-19). The fact that the top of the Sligo and bottom of the Pine Island, and the top of the James and bottom of the Rodessa are missing in all three wells suggests that erosion or nondeposition is involved rather than faulting (Crowe, 1975). This indicates that Vacherie Dome was a positive structural feature exhibiting periodic growth during the early Comanchean.

Domal growth during the middle to late Tertiary is difficult to evaluate because any sediments deposited during these times were subsequently removed by erosion. The Sparta Formation is the youngest Tertiary formation within the Vacherie Subbasin. Sparta, as well as older Cane River and Wilcox, sediments form an elliptical outcrop pattern of an inlier above Vacherie Dome (Figure 10-7), reflecting the domal uplift. Measurements of the attitudes of the beds obtained at the few available exposures show dips of 10 to 18 degrees (Figure 10-7, 10-17, and 10-18).

Horizontal resistivity profiles and vertical soundings were made by LETCo across accessible areas of Vacherie Dome during the summer of 1978, the spring of 1979, and the winter of 1981 (Figure 10-2). A Wenner array or configuration with an electrode spacing of 30 meters (100 ft) was used for the profiles, giving an average resistivity of the sediments to a depth of 30 meters (100 ft). Generally, differentiation could be made between sands (high resistivity) and clays (low resistivity) so that sand-clay contacts could be located along the profile lines. The wide electrode spacing provided resistivity measurements of sediments below the Quaternary-Tertiary contact; however, the sand-clay contacts in the Tertiary units were sometimes obscured by thick Quaternary sands or clays.

Reconnaissance field mapping was conducted by LETCo in the winter of 1981 (Law Engineering Testing Company, 1981). The field activities included, in addition to the resistivity surveys, identifying outcrops and, in their absence, hand-augering holes 0.9 to 3 meters (3 to 10 ft) deep and describing the sediment samples recovered. The mapping was conducted in more detail over the dome than in peripheral areas.

Identification and verification of the sand and clay units were made by evaluating the field mapping data and comparing it to available borehole data (Figure 10-2) to delineate surface and shallow subsurface (beneath the Quaternary cover) contacts between Tertiary formations. Good correlation was made between the clay and sand units identified by resistivity and the Cane River (clay), Sparta (sand), and Wilcox (sand) sediments identified by other means in borehole sections.

The structural interpretation over Vacherie Dome is based on the occurrence of Cane River, Sparta, and Wilcox strata in outcrops and in shallow and deep borings (as determined by paleontologic or geophysical evidence) at substantially different elevations over short horizontal distances. (See Figure 10-2 for well control and location of surface electrical resistivity surveys.) The surface locations and orientations of the fault traces are obscured by Quaternary deposits and by colluvium and were inferred. Fault locations and orientations were based on several types of evidence: the location of formation contacts observed at the surface or detected by resistivity surveys, the occurrence of straight stream valleys, and abrupt changes in alignment or orientation of a line of high hills across saddles. The amount of offset of formations of faults across fault lines shown on the maps and cross sections represents only the order of magnitude of the movement of the fault blocks. Where control is lacking, the fault planes are assumed to be high-angle with normal displacement.

Considering the areal extent of Vacherie Dome and the amount of structural disturbance in Tertiary formations indicated by the limited data collected, it is reasonable to assume that faulting of the Tertiary above Vacherie Dome is more prevalent and complex than presented here.

The occurrence of faulting above a salt dome such as Vacherie has been attributed to at least two different processes: (1) salt dissolution and subsequent collapse, and (2) the creation of tensional forces and normal faulting due to arching and stretching of the beds above the dome. There is no evidence of regional tectonism in the vicinity of the dome.

Downward displacement due to salt dissolution and collapse requires that the process occur at a faster rate than domal uplift. Ground-water flow over the dome must also be sufficient to enable fresh water to be brought continuously in contact with the salt body, as well as salt-saturated water to be transported away. The presence of caprock at Vacherie Dome, thought by some

(Taylor, 1938; Martinez and others, 1978) to form from residue left after domal salt dissolves, suggests to them that dissolution has occurred and may still be occurring.

The Sparta-Cane River and the Cane River-Wilcox contacts in several fault blocks above the dome occur well below the elevations of the same contacts away from the Dome (Figures 10-17 and 10-18). The occurrence of this structural configuration is more readily explained by dissolution and collapse than by uplift and normal faulting.

It is questionable, however, that dissolution and collapse acted alone at Vacherie to produce the observed faulting. A zone of collapse attributed to salt dissolution has been identified above Chestnut Dome in the southern portion of the study area. The zone is characterized by sand and clay overlying vertical beds of Cane River. Some of the beds are crushed and the fractures are filled by calcite veins. The net collapse may be as great as 610 to 762 meters (2,000 to 2,500 ft) and probably occurred in a hinge-like movement (Dinnean, 1958). Such collapse features have not been identified in wells above Vacherie Dome; however, Kolb (1977, 1978, 1979) identifies thick Quaternary deposits and zones of anomalous sands that may be indicative of a history of dissolution and collapse.

Model studies by Parker and McDowell (1955) indicate that slumping of sediments into voids, such as would be created by salt dissolution, is accompanied by reverse faulting. Although the nature of the faulting (normal or reverse) at Vacherie Dome is not known, very few reverse faults have been found associated with salt domes.

The apparent random distribution of wells which did not encounter Wilcox, Midway, and/or Taylor sediments in some of the fault blocks interpreted above Vacherie Dome (Figures 10-17 and 10-18), two of which were fully penetrated by LSU Hydrologic Wells V-7 and V-6, provides additional evidence that the faulting is probably not due entirely to dissolution and collapse. Some fault blocks that have Cane River in contact with the caprock are adjacent to other fault blocks which have Wilcox or Taylor in contact with the caprock. Vertical collapse into a void created by dissolution of the salt could not eliminate the older sediments to bring the Cane River Formation into contact with caprock.

The creation of tensional forces and normal faulting due to domal uplift has been suggested to explain the absence of older formations in some fault blocks above salt structures (Hughes, 1968). Upward movement of the salt mass and/or subsidence of the flanking sediments in the rim syncline create tensional forces in the strata over the dome as they are domed up and extended. A sequence of normal faults may then develop over the salt mass. Faulting of this type has been confirmed by field studies and duplicated in model studies (Hughes, 1968; Currie, 1956; Parker and McDowell, 1955).

The actual cause of the faulting at Vacherie Dome is unknown; it may be the result of both processes described (Kolb, 1978, 1979). Data from future drilling and high resolution seismic

[redacted]

reflection surveys may provide information that will help delineate faulting above the dome.

Lineaments detected on aerial photographs and radar imagery may also be indicators of faulting above Vacherie Dome (Figure 10-8). For example, some of the lineaments, particularly on the west side of the dome, coincide with interpreted radial faults (Figure 10-7). Two lineaments over the dome may correspond to anomalous, thick, stratified deposits of homogeneous silty sand that were penetrated by several shallow borings (Martinez and others, 1977). The age and origin of these deposits are still in doubt, but Kolb (1977) interpreted them to be late Tertiary to early Pleistocene in age, deposited in topographic lows created by salt dissolution and collapse.

Three curvilinear features on the eastern flank of Vacherie Dome, concave toward the dome, roughly correspond to the shape of the salt at depth. However, other randomly oriented curvilinear features in the same general area may constitute evidence that such features are not genetically related to the dome (Figure 10-8).

Lewis (1977) suggests that the lineaments that occur partially or wholly in Quaternary deposits near the dome indicate possible tectonic instability as recently as the Quaternary Period. Wobber (1967), however, found that bedrock fractures in Illinois are revealed as lineaments through up to 46 meters (150 ft) of apparently undisturbed Quaternary sediments. The lineaments in Quaternary deposits at Vacherie Dome, therefore, may reflect faulting in Tertiary rocks, rather than Quaternary.

10.1.3 MINERAL RESOURCES: Potential mineral resources at Vacherie Dome include sand, gravel, salt, gypsum, anhydrite, lignite, oil, and gas.

10.1.3.1 Sand and Gravel: Sand and gravel are present at Vacherie Dome in the substratum of Quaternary terraces and in the (Recent) alluvium of modern stream valleys. Sand also occurs in the unconsolidated Sparta Formation. Sand and gravel operations are not licensed by the state, therefore, no records of mining activities are available. Several large gravel pits, however, are evident on the topographic map of Vacherie (Figure 10-1), approximately 5 km (3 mi) west of the dome. Glass sand is being mined from the Sparta Formation by Dresser Industries 3 km (2 mi) north of the dome. The general availability and abundance of sand and gravel throughout the Gulf Coast Region precludes the development of important operations at Vacherie.

10.1.3.2 Salt: Salt is present at Vacherie in the dome and in deep beds. The depth to either source of salt [213 meters (700 ft)] to the top of the dome makes mining or brining unprofitable in comparison to abundant nearby deposits at shallower depths.

10.1.3.3 Gypsum and Anhydrite: Gypsum and anhydrite are present in the caprock of Vacherie Dome but, as with salt, they are too deeply buried to be mined profitably.

10.1.3.4 Lignite: Lignite occurs at Vacherie in the Wilcox Group and to a lesser extent in the Sparta Formation. A 1.2 meter (4 ft) lignite seam has been penetrated by a Louisiana State University hydrologic well (V-5) at a depth of 7 meters (22 ft) (Martinez and others, 1977). The economic importance of this or other seams at Vacherie Dome is unevaluated. However, thicker, shallower lignite seams of known grade are present in DeSoto and Sabine Parishes.

10.1.3.5 Oil and Gas: Vacherie Dome is surrounded by four oil and gas fields: Sibley, Ada, Sailes, and Fryeburg (Figure 9-29). Production closest to the dome occurs 3 km (2 mi) to the northeast in Ada Field (Martinez and others, 1977). All wells drilled to date on the flanks of the dome have been dry and abandoned. On the northeast flank the most recent wildcat at Vacherie (Nelson Oil and Gas #1 Rowland) was dry, and it was abandoned in October, 1979 at a depth of 2,409 meters (7,905 ft). All but the northwest flank have been drilled since the early 1920's without production. The probability of finding substantial quantities of oil or gas at Vacherie Dome is low (Murray, 1979).

10.2 RAYBURN'S DOME

Rayburns Dome is located in southeastern Bienville Parish, Louisiana (Figure 9-1). The nearest towns are Saline (pop. 300), 10 km (6 mi) to the southwest; Friendship (unincorporated community), 3 km (2 mi) to the east; Jonesboro (pop. 5,000), 18 km (11 mi) to the east; and Hodge (pop. 900), 18 km (11 mi) to the east-northeast.

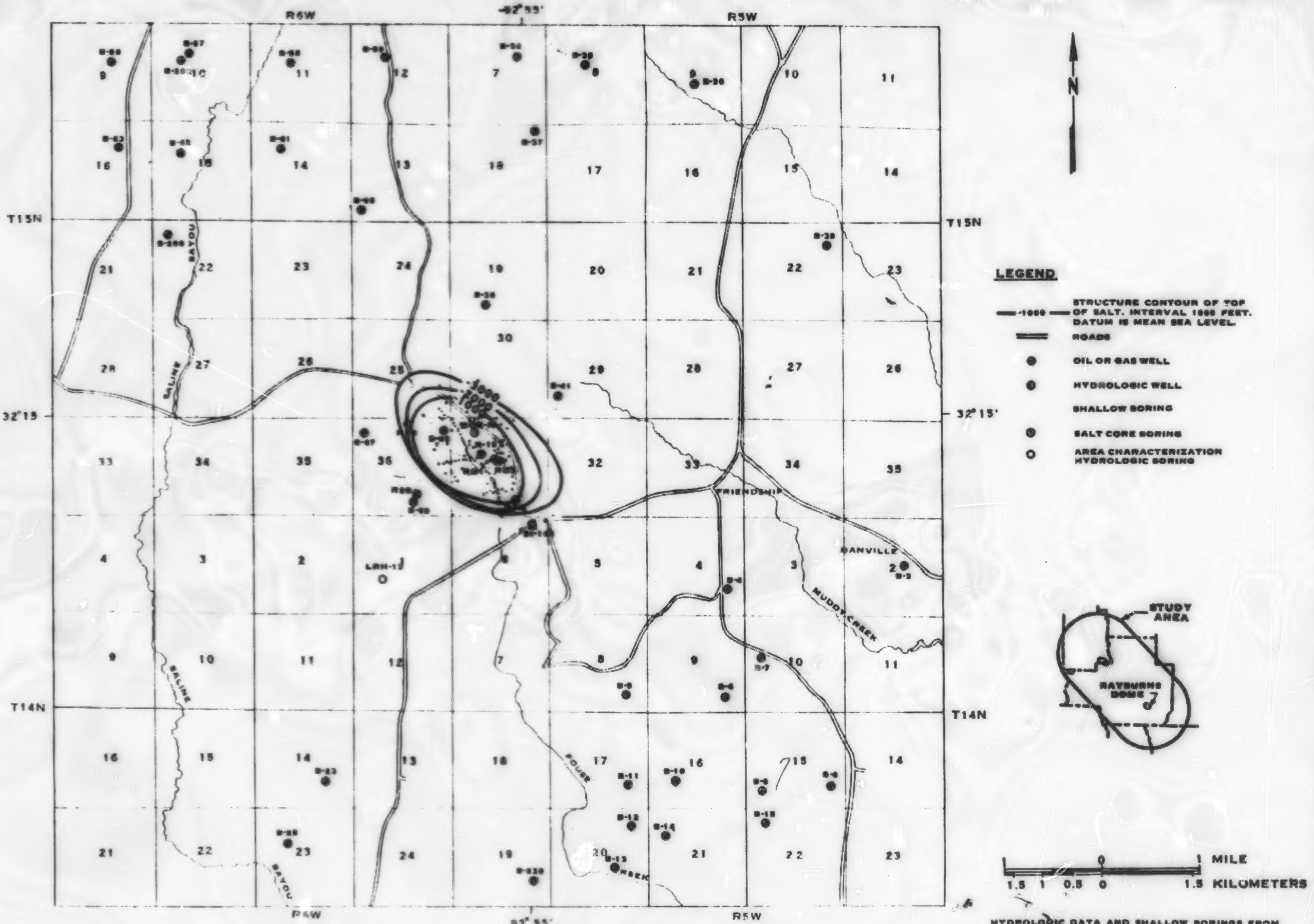
Forestry and agriculture are the principal land uses in the area. The major portion of the land area above the dome and in the vicinity is either owned in fee or leased by Continental Forest Industries. Numerous other privately owned tracts of land in the area vary in size from about 16 to 65 hectares (40 to 160 acres). Examination of aerial photographs taken in 1978 determined that approximately 49 hectares (120 acres) were under cultivation at the south end of the dome where a poultry farm was also in operation. Surficial or shallow subsurface mineral resources near Rayburn's Dome include sand and gravel, rock salt, limestone, brine, and lignite. (See section 10.2.3 for a discussion of mineral resources near Rayburn's Dome.)

The following sections include interpretations of the geometry of the salt, the near-dome geology, and mineral resources in the dome vicinity. Locations of well data used in the interpretations are shown in Figure 10-20. Wells within the projection of the -914-meter (-3000-ft)-MSL salt contour to the surface are listed in Table 10-2. Wells within a 8-km (5-mi) radius of the dome are listed in North Louisiana Study Area Appendix Table A.3-2.

10.2.1 DOME GEOMETRY AND COMPOSITION: Gravity modeling and sparse well data indicate that, in shallow profile to -3,048 meters (to -10,000 ft MSL), Rayburn's Dome has a bulbous shape with a circumferential overhang (Figure 10-21). From the top of the dome down to the elevation of the maximum diameter of the overhang between -914 and -1,219 (-3,000 and -4,000 ft) MSL the sides slope at approximately a 45° angle from the vertical. Downward from this point, the slope reverses as the diameter decreases to its minimum at -3,048 meters (-10,000 ft) MSL. Below this depth the sides of the dome flare out again and the diameter increases down to -6,096 meters (-20,000 ft) MSL.

In plan view, Rayburn's Dome is oval with the long axis oriented northwest-southeast (Figures 10-22 and 10-23). At -610 (-2,000 ft) MSL, the total area of the dome is 320 hectares (790 acres); at -762 meters (-2,500 ft) MSL, 374 hectares (924 acres); and at -914 meters (-3,000 ft) MSL, 438 hectares (1,082 acres). Penetrations of the salt are shown on Figure 10-24 and listed in Table 10-2.

Depths to caprock, encountered in wells within the projection of the -914-meter (-3,000-ft)-MSL contour to the surface, range from 5 to 50 meters (18 to 165 ft) [+53 to 23 meters (+174 to +77 ft) MSL], and the thickness varies from 1 to 27 meters (3.5 to 88 ft). As interpreted from gravity and sparse well data, the caprock appears to cover the top of the salt stock and drape the flanks to an elevation of approximately -1,067 meters (-3,500 ft) MSL (Figures 10-23 and 10-24). The surface of the caprock is irregular and is overlain by a limestone boulder zone consisting of calcite boulders, cobbles, and gravels in a matrix of dark gray, sandy clay, or clayey sand with occasional 152 to 762-mm (6 to 30-in)-thick sand to silt stringers (1979). The zone is interpreted by Kolb (1979) to be "water-worn fragments of a once



HYDROLOGIC DATA AND SHALLOW BORINGS FROM MARTINEZ AND OTHERS, 1976, 1977, 1978, 1979.

NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
LOCATION OF WELL DATA
USED IN ANALYSIS

JOB NO. MV9600

FIGURE 10-20

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

PREPARED DATE 12/18/80
REVISED DGH DATE 11/2/81
REVISED DATE 12/23/80
APPROVED GHF DATE

T-1379-2

FIGURE 10-20

BEST DOCUMENT AVAILABLE

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Table 10-2

BOREHOLE DATA SUMMARY

RAYBURNS DOME

WELL NAME	LETCo WELL NO.	LOCATION	GROUND ELEV.* (FT.)	TOTAL DEPTH (FT.)	LOGS RUN	OUTSIDE CASING DIAM. (IN.)/ CASING DEPTH (FT.)	GROUTING	CASING SEAT DEPTH (FT.)	ABANDONMENT PROCEDURE	ELEVATION CAPROCK TOP*/ THICKNESS (FT.)	ELEVATION SALT TOP*/ THICKNESS (FT.)	SOURCE	REMARKS
Brining Operation		Sec 31-15N-5W	190 - 200	20-30	NA	NA	NA	NA	NA	Some wells possibly encountered caprock	Not known if salt encountered		Borings made in 1840-1877 See separate report on Rayburn's Salt Works
#1 Dorman	RD 1	Center of Sec 31-15N-5W	195 (est)	37	NA	NA	NA	NA	NA	Well abandoned in caprock		Shreveport Geol. Society Guidebrok, 1960	Drilled: 1910 D & A
#2 Dorman	RD 2	Center of Sec 31-15N-5W	195 (est)	85	NA	NA	NA	NA	NA	Well abandoned in caprock		Shreveport Geol. Society Guidebook, 1960	Drilled: 1910 D & A
Hodge-Hunt #3 Fee	R 157	NW, SE, NW Sec 31-15N-5W	195 (est)	277	NA	NA	NA	NA	NA	124/30	94/162	Shreveport Geol. Society Guidebook, 1960; Spooner, 1926	Drilled: 12/23 D & A Rayburns Dome Discovery Well
Hodge-Hunt #3 Cont. Can	B 68	C of NE, NE Sec 36-15N-6W	230 (est)	709	SP-Resistivity CST	8 5/8 / 151	155 sx	151	NA	77/88	-11/456	Geoph. Log; Dept. of Consv. Well History Rept.	Drilled: 6/57 D & A
DOE #1 Cont. F. I.	DOE-R	310'N, 1430'W of SE/c,N½, NW Sec 31-15N-5W	215	5013	Dual Later. Comp. Sonic Comp. Dens. Frac. I. D. Cont. Direc. Temp. Caliper Gamma Dipmeter	9 1/2 / 71	200 sx	71	Hole left open, Filled w/brine Flange well head installed	91.5/3.5	88/4874.5	Coreholes at Vacherie and Rayburns Salt Domes, L.S.U., 1978 Martinez and others, 1979	Drilled: 4/78 Rayburns Salt Core Hole
LETCo Shallow Borings	C9BE	NE, NE, NW Sec 31-15N-5W	205	45	None	None	--		Backfilled to T. D.	179/19	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	C10A	NE, NW, NW Sec 31-15N-5W	220	96	None	None	--		Backfilled to T. D.	130/8	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	A16E	SE, SE, NE Sec 36-15N-6W	214	134	None	None	--		Backfilled to T. D.	83/3	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	X2E	NW, NW, NW Sec 31-15N-5W	218	134	None	None	--		Backfilled to T. D.	135/51	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	X18E	NE, NE, SW Sec 31-15N-5W	192	96.5	None	3"PVC/76	NA	76	Screen set from 40' to 45'	102/6.5	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	A7E	NE, SW, NW Sec 31-15N-5W	193	47.5	None	3"PVC/46	NA	46	Screen set from 16' to 21'	155/9.5	Salt not encountered	LETCo Files	Drilled: 8,9,10/79

NA-Not Available
*Datum is mean sea level.

Table 10-2
BOREHOLE DATA SUMMARY
RAYBURNS DOME
(CON'T)

WELL NAME	LETCo WELL NO.	LOCATION	GROUND ELEV.* (FT.)	TOTAL DEPTH (FT.)	LOGS RUN	OUTSIDE CASING DIAM(IN)/ CASING DEPTH (FT.)	GROUTING	CASING SEAT DEPTH (FT.)	ABANDONMENT PROCEDURE	ELEVATION CAPROCK TOP*/ THICKNESS (FT.)	ELEVATION SALT TOP */ THICKNESS (FT.)	SOURCE	REMARKS
LETCo Shallow Borings	X15AE	SW, SE, NW Sec 31-15N-5W	192 (est)	39.5	None	3"PVC/39.5	NA	39.5	Screen set from 20' to 25'	160/7.5	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	X19E	NE, NE, SW Sec 31-15N-5W	192 (est)	39.5	None	3"PVC/39.5	NA	39.5	Screen set from 10' to 15'	174/21.5	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	A4E	NW, SE, NW Sec 31-15N-5W	195	85	None	3"PVC/85	--	85	NA	125/12	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	A2E	NE, SW, NW Sec 31-15N-4W	196	95.5	None	None	--	--	Grouted to T. D.	101.5/1	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	A9E	SE, SW, NW Sec 31-15N-5W	197	50	None	None	--	--	Grouted to T. D.	155/8	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	X11E	NE, SW, NW Sec 31-15N-5W	196	45	None	None	--	--	Grouted to T. D.	155.5/4.5	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	C9B	NE, NE, NW Sec 31-15N-5W	204	25	None	None	--	--	Backfilled to T. D.	179.5/0.5	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	C9A	NW, NE, NW Sec 31-15N-5W	203	130	None	None	--	--	Grouted to T. D.		Obtained a few Salt flecks at 130'	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	X6EB	SW, NW, NW Sec 31-15N-5W	202	102	None	None	--	--	Grouted to T. D.	102/2	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo Shallow Borings	26 Additional Borings	Sec 30 31-15N-5W Sec 25 36-15N-6W	202 to 250	10 to 100	None	None	--	--	All wells backfilled to T. D.	Caprock not encountered	Salt not encountered	LETCo Files	Drilled: 8,9,10/79
LETCo & LSU Shallow Borings	X9	SE, NW, NW Sec 31-15N-5W	197	52	NA	None	--	--	NA	146/1	Salt not encountered	Martinez et al, 1978	Drilled: 1977 LSU 7,8/78 LETCo
LETCo & LSU Shallow Borings	X13	NW, SE, NW Sec 31-15N-5W	194	46	NA	None	--	--	NA	151/3	Salt not encountered	Martinez et al, 1973	Drilled: 1977 LSU 7,8/78 LETCo
LETCo & LSU Shallow Borings	X14	NW, SE, NW Sec 31-15N-5W	192	39	NA	None	--	--	NA	158/5	Salt not encountered	Martinez et al. 1978	Drilled 1977 LSU 7,8/78 LETCo
LETCo & LSU Shallow Borings	A10	SE, SW, NW Sec 31-15N-5W	200	60	NA	None	--	--	NA	142/2	Salt not encountered	Martinez et al, 1978	Drilled: 1977 LSU 7,8/78 LETCo

NA-Not Available
*Datum is mean seal level.

Table 10-2

BOREHOLE DATA SUMMARY

RAYBURNS DOME

(CON'T)

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WELL NAME	LETCo WELL NO.	LOCATION	GROUND ELEV.* (FT.)	TOTAL DEPTH (FT.)	LOGS RUN	OUTSIDE CASING DIAM. (DI.)/ CASING DEPTH (FT.)	GROUTING	CASING SEAT DEPTH (FT.)	ABANDONMENT PROCEDURE	ELEVATION CAPROCK TOP*/ THICKNESS (FT.)	ELEVATION SALT TOP*/ THICKNESS (FT.)	SOURCE	REMARKS
LETCo & LSU Shallow Borings	A11	SE, SW, NW Sec 31-15N-5W	200	59	NA	None	--	--	NA	145/4	Salt not encountered	Martinez et al, 1978	Drilled: 1977 LSU 7,8/78 LETCo
LETCo & LSU Shallow Borings	23 LETCo 46 LSU Additional Borings A, X,Y,AA, R,K lines	Sec 31-15N-5W Sec 25 36-15N-6W Sec 6-14N-5W	190 to 242	10 to 134	E-Logs run in a few wells	None	--	--	NA	Caprock not encountered	Salt not encountered	Martinez et al, 1978	Drilled: 1977 LSU 7,8/78 LETCo
LSU Shallow Borings	1	SW, NW, NE Sec 31-15N-5W	212	53	NA	None	--	--	NA	162/3	Salt not encountered	Martinez et al, 1976	Drilled: 6,7/76
LSU Shallow Borings	X2,3 4,5,6	Sec 31-15N-5W Sec 36-15N-6W	212	14 to 76	NA	None	--	--	NA	Caprock not encountered	Salt not encountered	Martinez et al, 1976	Drilled: 6,7/76
DOE LSU Rayburns Dome	R1A	NE, SW, SE Sec 31-15N-5W	230	1112	SP-Resistivity Sonic Dipmeter	7/59.6	Cem. to Sur.	462	Ground Water Observation Well USGS Bi 183	Caprock not encountered	Salt not encountered	Martinez et al, 1978	Drilled: 9/77 Screened 477.8'-488.1'
DOE LSU Rayburns Dome	R3B	NW, NW, NE Sec 36-15N-6W	250	1111	SP-Resistivity Dipmeter Sonic	5½/656	Cem. to Sur.	656	Ground Water Observation Well USGS Bi 185	Caprock not encountered	Salt not encountered	Martinez et al, 1978	Drilled: 10/77 Screened 656'-666'

NA-Not Available

*Datum is mean sea level.

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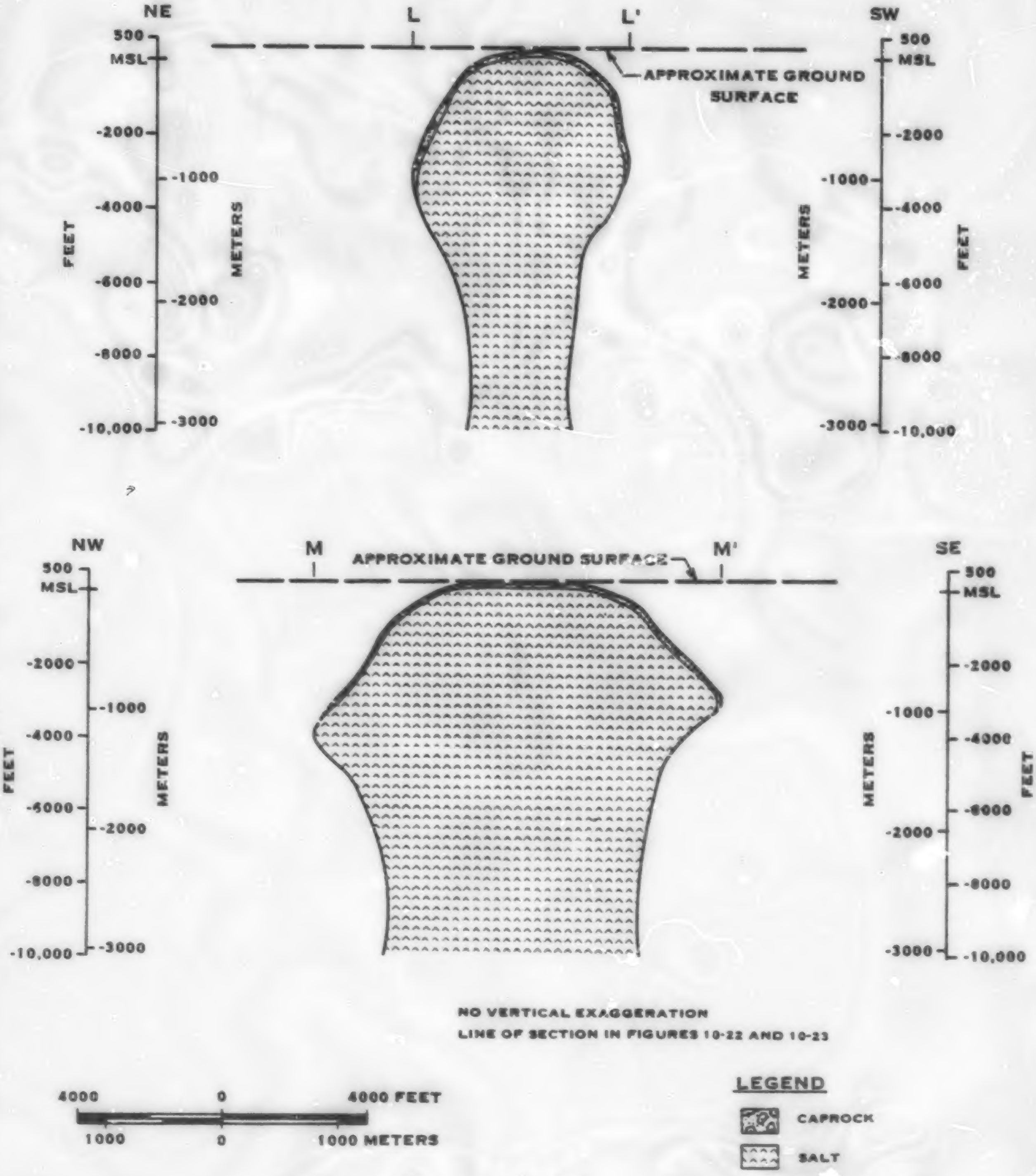

NO VERTICAL EXAGGERATION

LINE OF SECTION IN FIGURES 10-22 AND 10-23

PREPARED BH DATE
REVISED DATE
REVISED DATE
APPROVED DGO DATE 12/12/

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
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NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
GEOLOGIC SECTION L-L' AND M-M'

JOB NO. MV9600 FIGURE 10-21

[redacted] 171 BEST DOCUMENT AVAILABLE

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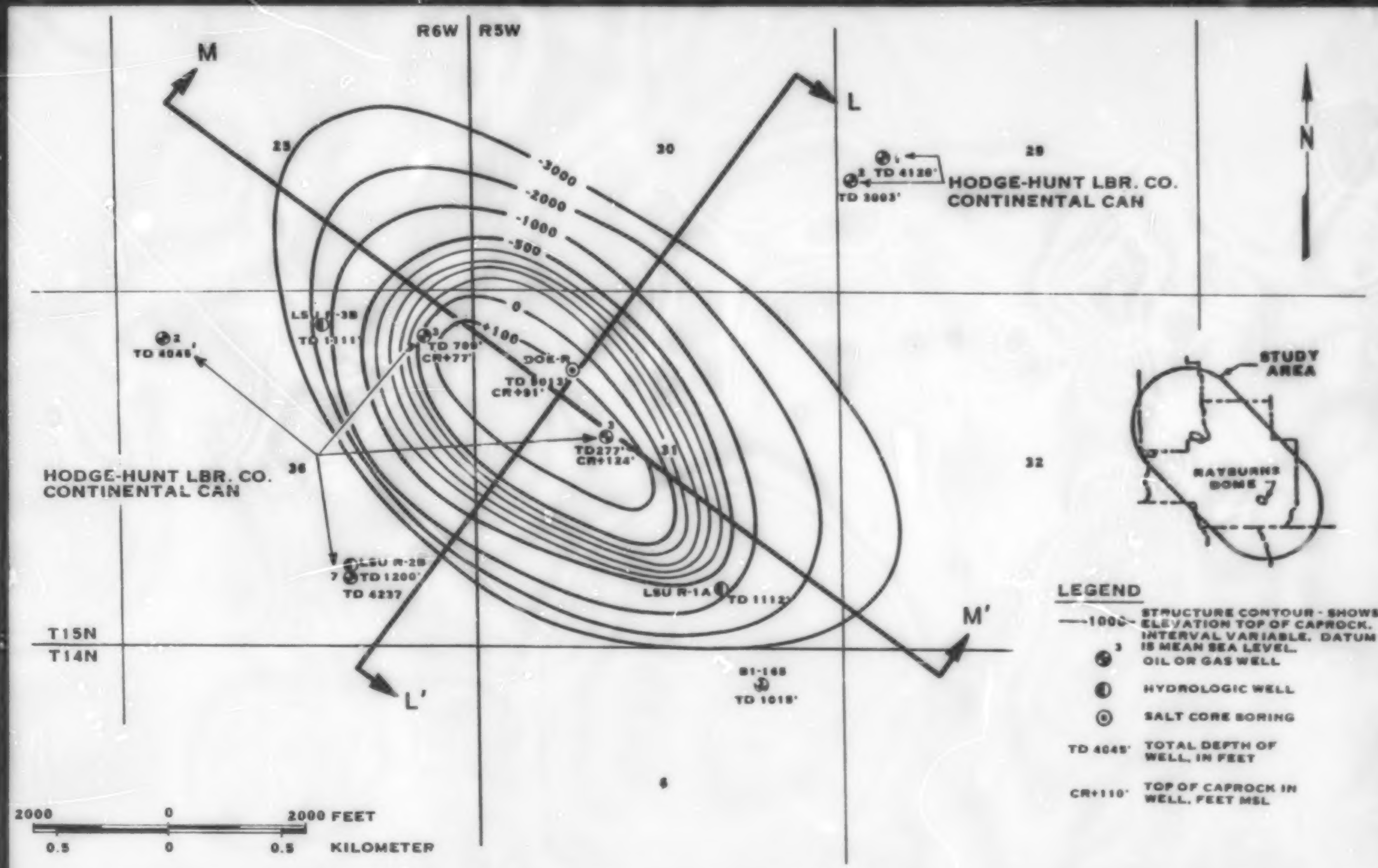

PREPARED Jmc. DATE 12/18/80
REVISED CDP DATE 1/9/81
REVISED ______ DATE ______
APPROVED GHF DATE 12/23/80
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NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
STRUCTURAL CONTOUR MAP
TOP OF CAPROCK
JOB NO. MV9600
FIGURE 10-22

FIGURE 10-22

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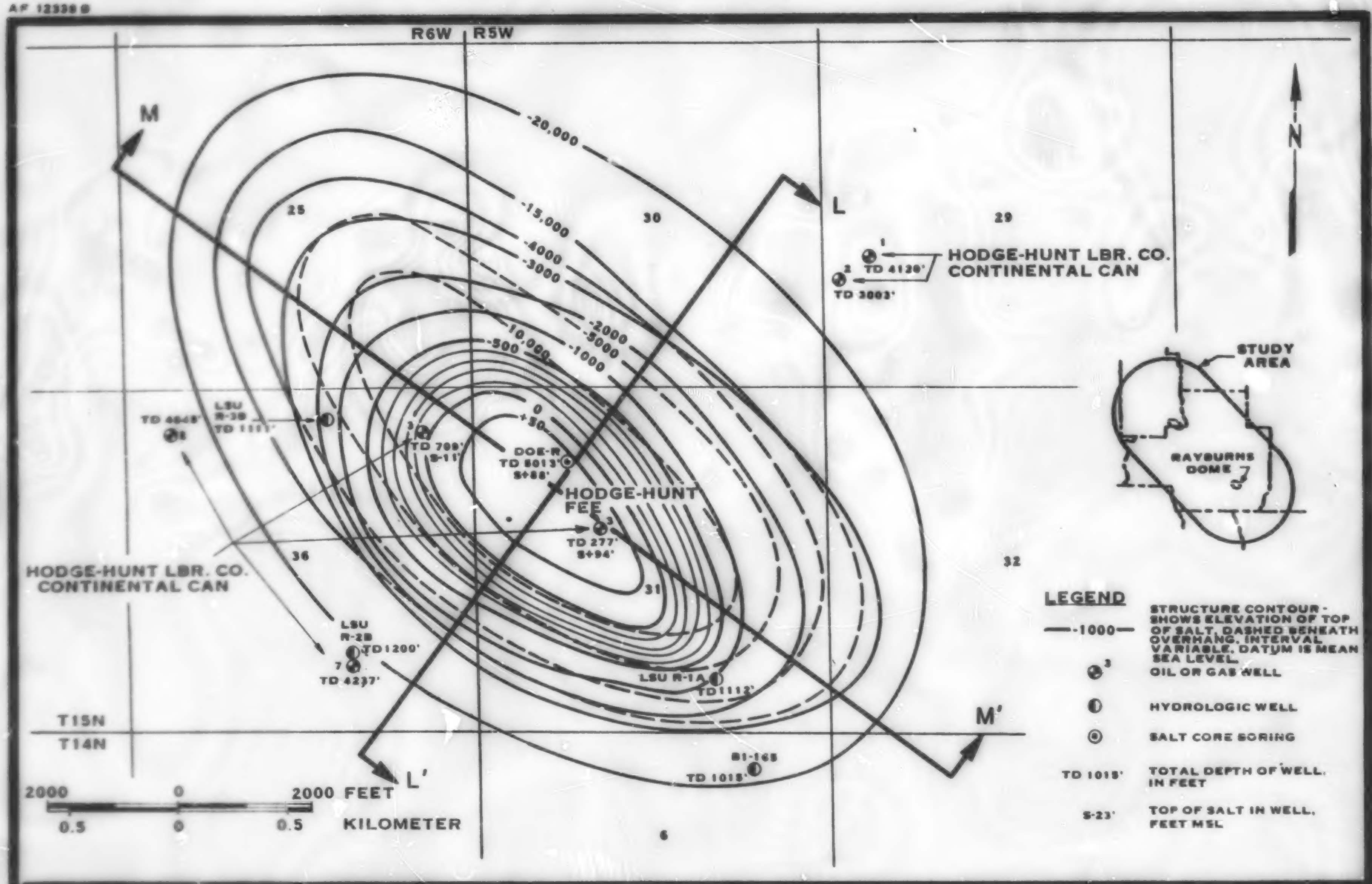

PREPARED ______ DATE 12/15/80
REVISED ______ DATE 1/8/81
REVISED ______ DATE ______
APPROVED ______ DATE 12/23/80

T-1383-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
STRUCTURAL CONTOUR MAP
TOP OF SALT

JOB NO. MV9600

FIGURE 10-23

FIGURE 10-23

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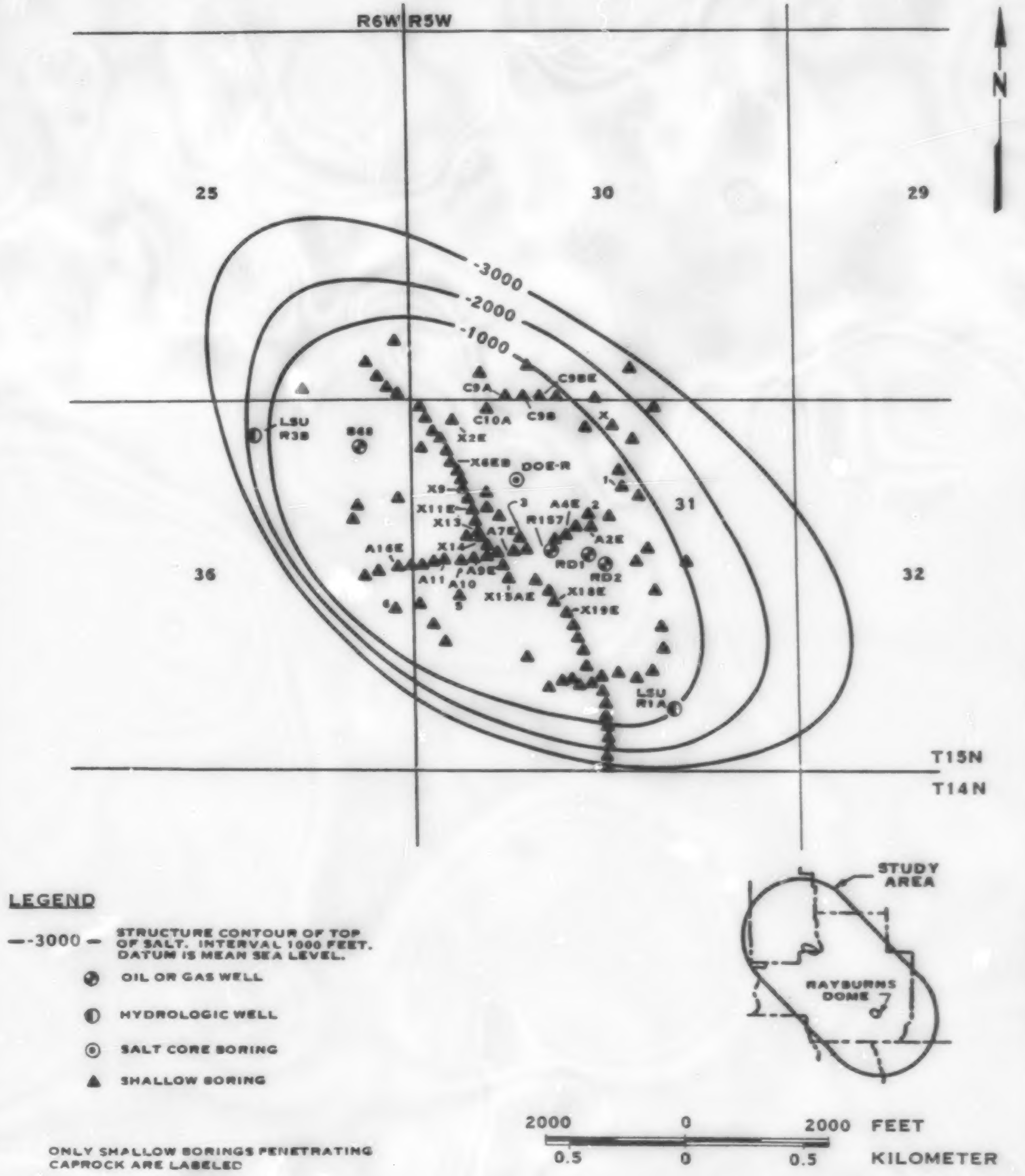
AF 12338A



LEGEND

—-3000— STRUCTURE CONTOUR OF TOP OF SALT. INTERVAL 1000 FEET. DATUM IS MEAN SEA LEVEL.

◐ OIL OR GAS WELL

◐ HYDROLOGIC WELL

◎ SALT CORE BORING

▲ SHALLOW BORING

2000 0 2000 FEET

0.5 0 0.5 KILOMETER

ONLY SHALLOW BORINGS PENETRATING CAPROCK ARE LABELED

SEE TABLE 10-2 FOR INFORMATION ON WELLS AND BORINGS.

PREPARED ____ DATE 12/15/80

REVISED ____ DATE 12/21

REVISED ____ DATE ____

APPROVED GHF DATE 12/22/80

T-1384-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM

GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

NORTH LOUISIANA STUDY AREA

RAYBURNS DOME

MAP OF PENETRATIONS OF DOME AND OVERBURDEN

JOB NO. MV9600 FIGURE 10-24

continuous calcite caprock that was exposed to subaerial erosion in past geologic time. The most durable and water-resistant fragments of this caprock cover have now been let down on top of the dome as a bouldery cover".

An alternative explanation suggested by Kolb (1979) is that subsurface dissolution by ground water along joints and fractures produced boulder and cobble-size fragments. The lack of pollen within the boulder zone suggests, but does not prove, that the boulder zone was not subaerially exposed.

In the Rayburn's salt corehole (D.O.E. #1 Cont. Forest Ind.), depth to caprock is 41 meters (135 ft) [+28 meters (+91 ft) MSL]. Core recovery was poor in the caprock and in the intervals above and below so that only a limited amount of data could be collected for this portion of the section (Nance and Wilcox, 1979). The caprock that was recovered from this interval consists of light gray to yellow-brown, brown and black, brecciated and massive limestone, which sometimes contains solution cavities and angular rock fragments 6 mm (0.25 in) in diameter. Below this is a zone of more massive, less brecciated character, composed of massive anhydrite with gypsum bands. The nature of the caprock/salt interface is not known because the section of core containing this contact was not recovered.

Depths to salt encountered in wells within the -914-meter (-3,000-ft)-MSL contour range from 35 to 77 meters (115 to 253 ft) [+29 to -3 meters (+94 to -11 ft) MSL] and in the Rayburn's core hole the depth to salt is 42 meters (138.5 ft) [+27 meters

(+88 ft) MSL]. The Rayburn's salt core seems to have a simpler internal composition and structure than does the Vacherie core. The Rayburn's core is characterized by uncontorted, sub-parallel layers of halite and diffuse anhydrite in halite, forming anhydrite bands. Anhydrite crystals are consistently less than 0.5 mm (0.02 in) throughout the core. Folding is present, but it appears to have been gradual, extending over long intervals. No small-scale isoclinal folding was seen within the core. The anhydrite seems to be more uniformly distributed but lower in percentage composition than at Vacherie (approximately 95 percent halite and 5 percent anhydrite at Rayburn's compared with approximately 90 percent halite and 10 percent anhydrite at Vacherie). There appears to be a greater variety of grain sizes of halite and a greater number of large crystals with depth at Rayburn's.

The salt core is characterized to a depth of 335 meters (1,100 ft) [-266 meters (-874 ft) MSL] by a medium-grain 6.3 to 25 mm (0.25 to 1.0 in) halite matrix which displays a preferred orientation of crystals, and numerous steeply dipping layers of impure halite containing dispersed, fine-grain 0.5 mm (0.02 in), diffuse anhydrite bands, usually less than 51 mm (2 in) thick. Below 335 meters (1,100 ft) [-266 meters (-874 ft) MSL] the halite crystals become equidimensional and coarsely crystalline > 51 mm (>2.0 in). Some isolated coarse crystals are as long as 457 mm (18 in). Diffuse anhydrite bands are present, becoming thicker and more evenly spaced with depth (Nance and Wilcox, 1979).

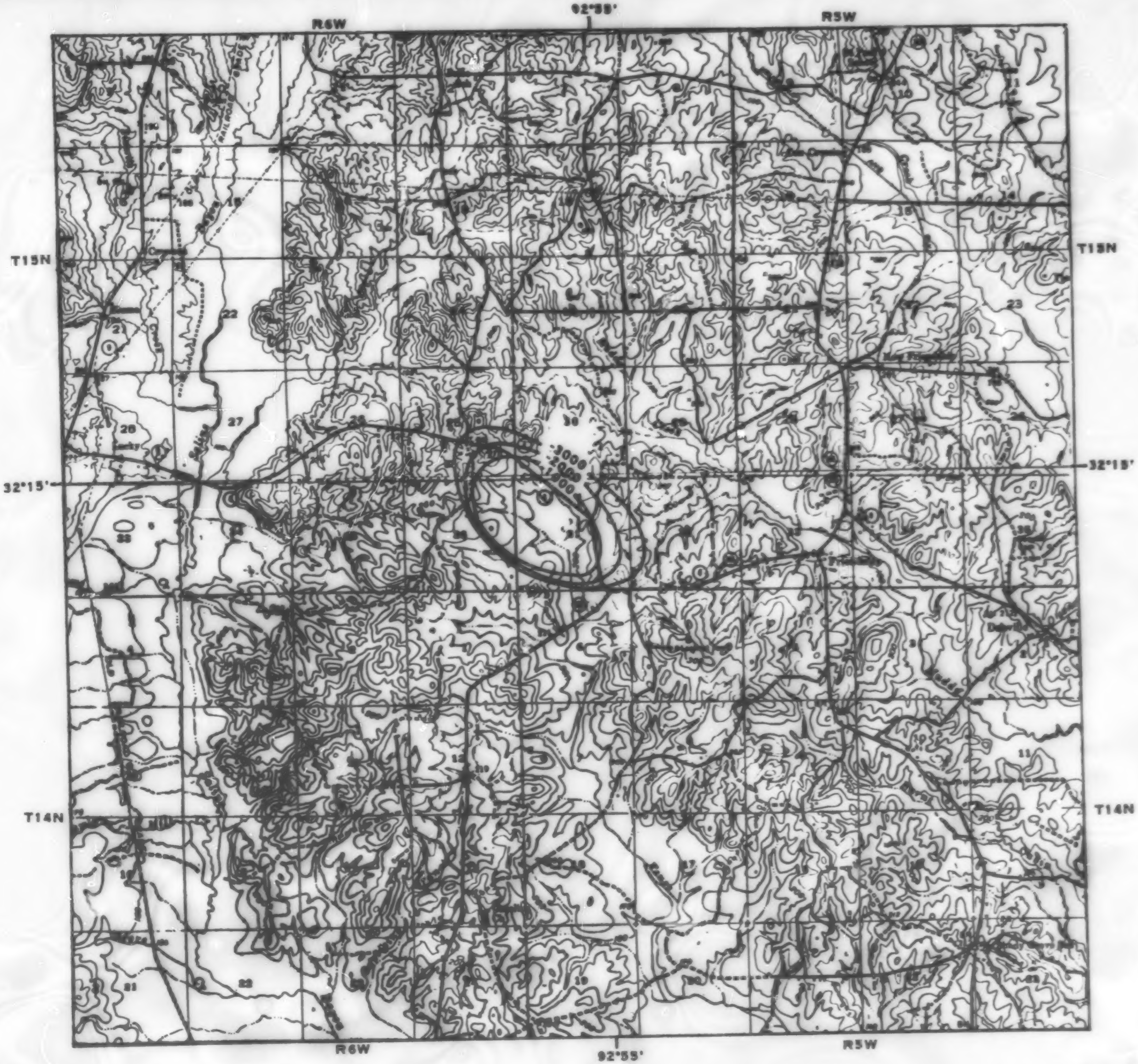
According to Smith (1977), a shale sheath surrounds Rayburn's Dome, separating the salt body from adjacent aquifers. The sheath may be composed of Midway clays. Smith believes that the presence of nonsaline (fresh) ground water in deep aquifers -335 meters (-1,100 ft) MSL near the dome suggests the existence of the sheath.

10.2.2 NEAR-DOME GEOLOGY:

This section includes interpretations of surface features, stratigraphy, and structure of the strata surrounding the Dome.

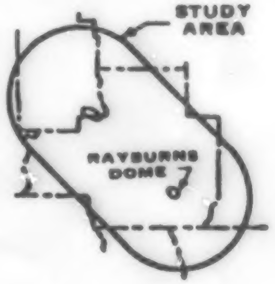
10.2.2.1 Surface Features: Rayburn's Dome is expressed at the surface by a circular topographic low surrounded by hills with 18 to 30 meters (60 to 100 ft) of relief (Figure 10-25). A saline occupies the central depression into which intermittent streams flow from the surrounding hills. This swampy area is drained to the south by Fouse Creek, a tributary of the Dugdemona River.

The surface geology in the Rayburn's Dome area consists of Cretaceous, Tertiary, and Quaternary sediments. The upper Eocene Sparta Formation is exposed over most of the area and forms a resistant ridge which almost circles the central depression (Figure 10-26). Steeply dipping lower Tertiary and Upper Cretaceous inliers form concentric rings within the central depression but are often covered by alluvium washed from the surrounding hills. The alluvial cover hinders mapping of the surface; therefore, shallow boring and oil well logs, published reports (Martinez and others, 1976, 1979; Shreveport Geological Society, 1960; Butler and Jones, 1957), and low-altitude aerial



LEGEND

—-1000— STRUCTURE CONTOUR OF TOP OF SALT. INTERVAL 1000 FEET. DATUM IS MEAN SEA LEVEL.



1 0 1 MILE

1 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET.
DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY 1:62,500 QUADRANGLES.

NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
TOPOGRAPHIC MAP WITH
STRUCTURAL CONTOURS ON THE SALT

JOB NO. MV9600 FIGURE 10-25

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED TMC DATE 12/18/80
REVISED DJD DATE 11/01/81
REVISED DATE
APPROVED GHF DATE 12/23/80

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FIGURE 10-25

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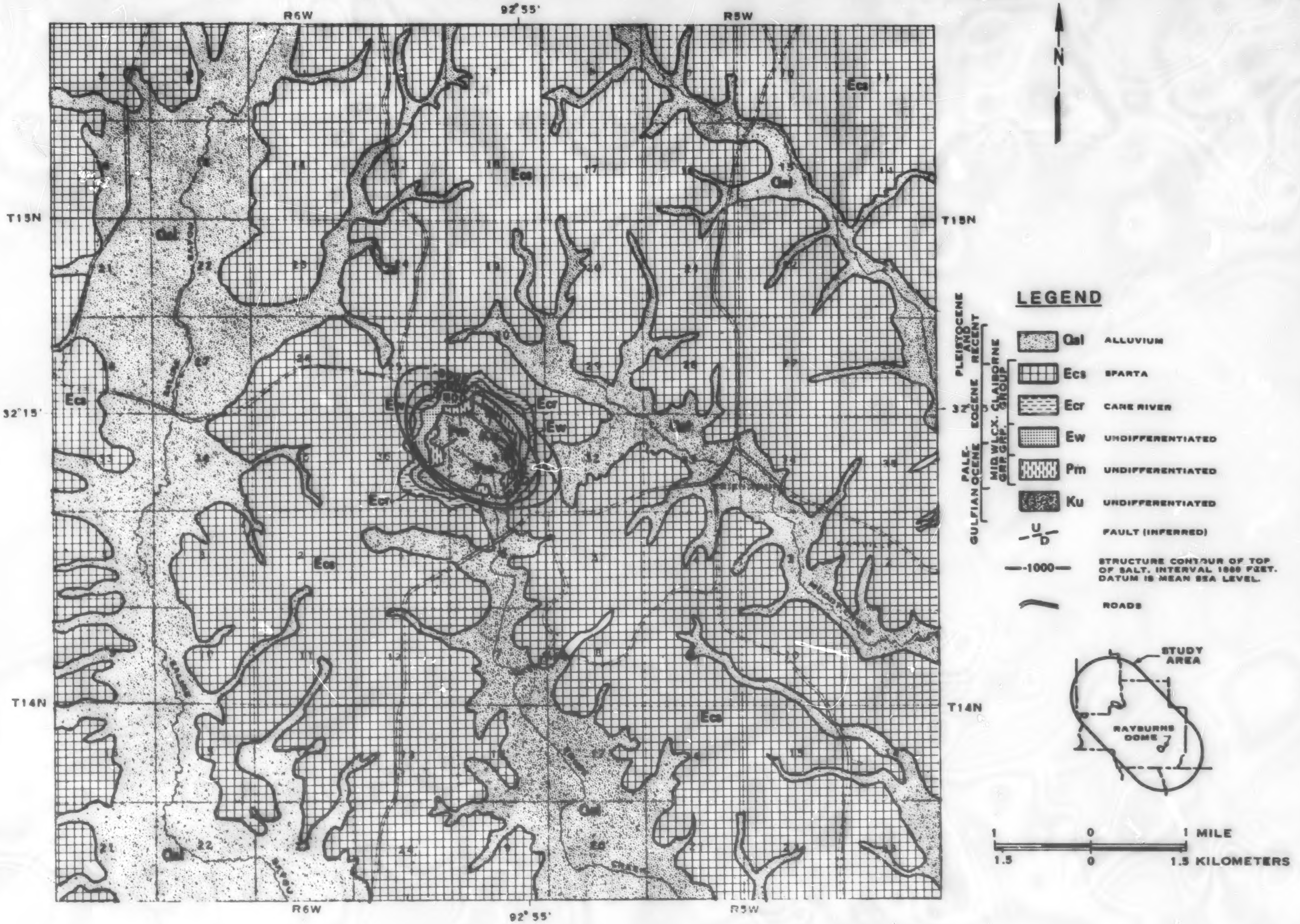

NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
SURFACE GEOLOGIC MAP

JOB NO. MV9600

FIGURE 10-26

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA GEORGIA

PREPARED Jmc DATE 10/18/82
REVISED CJP DATE 11/2/81
REVISED ______ DATE 12/23/80
APPROVED GHF DATE

T-1387-2

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FIGURE 10-26

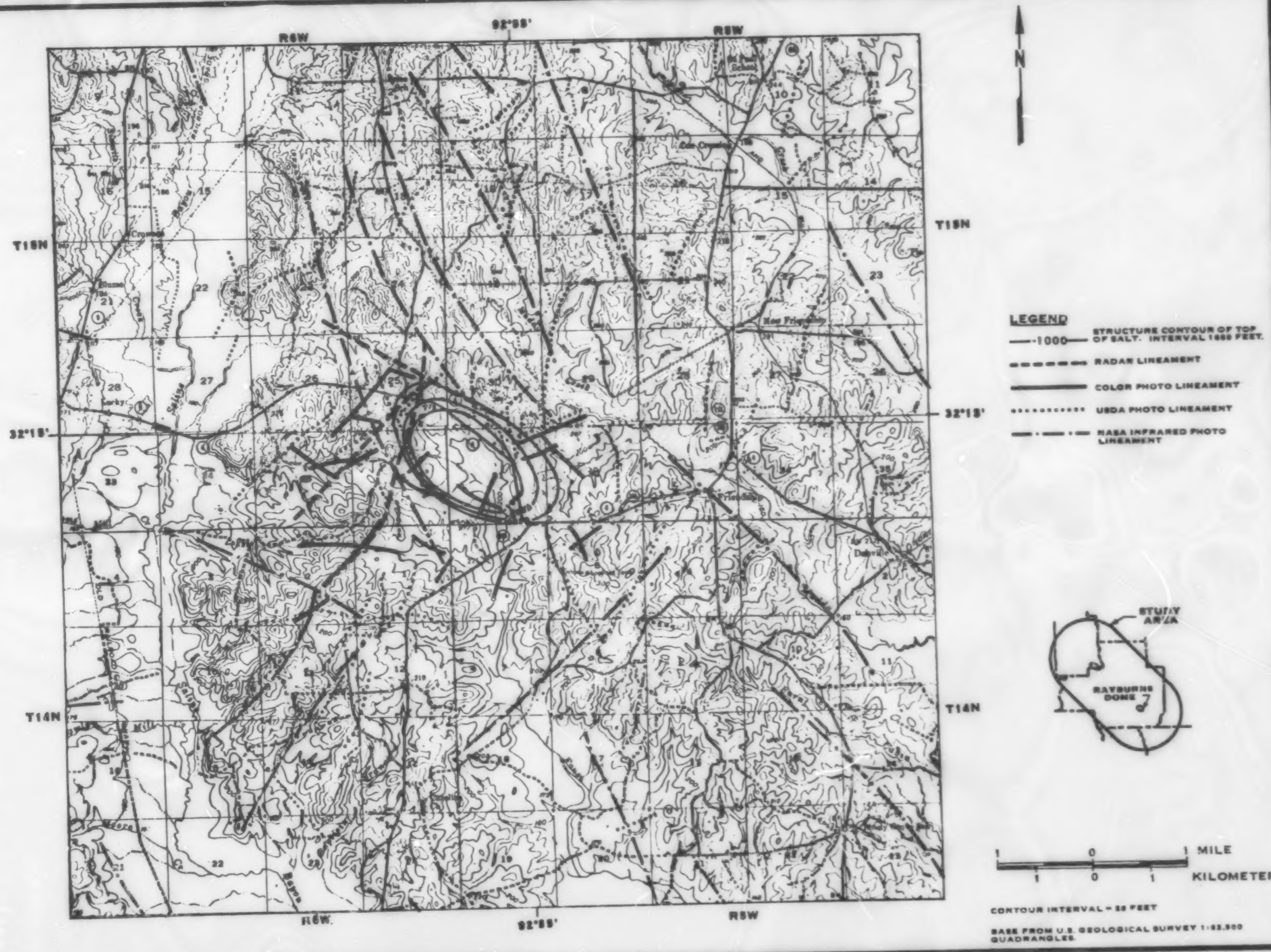
photographs are the primary sources of data for the geologic interpretation.

The lower Tertiary units exposed at Rayburn's Dome are the Cane River Formation and the Wilcox and Midway Groups, all three of which are abnormally thin in the outcrop. The Upper Cretaceous outcrop on the eastern and northeastern edge of the central depression has been identified through its fossil content to be part of the Saratoga Formation (Butler and Jones, 1957). A phosphatic boulder zone, usually indicative of submarine erosion, forms the Upper Cretaceous-Midway contact (Durham and White, 1960). Upper Cretaceous rocks may be close to the surface on the other sides of the central depression but, if so, are covered by Pleistocene deposits.

Pleistocene deposits here are similar to those above Vacherie Dome. Chert gravels at Rayburns directly overlie caprock or a limestone boulder zone; they are thicker on the eastern, northern, and western sides of the depression and thinnest over the central part of the Dome. Kolb (1979) suggests this indicates that either the central depression was previously drained by an outlet other than Fouse Creek, or that the outer edges of the salt dome collapsed due to salt dissolution during and after the Pleistocene, and that shallow boring data suggest the latter case to be more plausible. A similar condition was found at Vacherie Dome where Quaternary deposits are thicker at the western end of the Dome, but terraces indicate drainage to the east. Kolb (1979) identifies one, and possibly two Quaternary terrace levels within the central depression over Rayburn's Dome. The terrace deposits consist of gravel and silty sand grading upward into silts and clays. Palynological studies indicate that the sediments at a depth of 4 to 5 meters (14 to 15 ft) were deposited in a climate colder than today's, probably during a glacial period, and that the area over the dome was flooded for significant periods of time in the geologic past (Martinez and others, 1979).

Quaternary studies at Rayburn's Dome have not provided any information about the stability of the dome. The identified terraces have not been profiled or dated. Lineaments interpreted from remote sensing data occur in Quaternary deposits (Figure 10-27); however, faulting of the Quaternary deposits, which would indicate post-depositional domal movement, has not been detected. Disturbances of the surface and shallow subsurface over the Dome, including a salt works during the Civil War period and a more recent limestone quarry, greatly hamper the complete interpretation of Quaternary history at Rayburn's Dome.

10.2.2.2 Stratigraphy: The following section discusses the lithologies of the stratigraphic units from the base of the Rusk Formation of the Trinity Stage/Group to the Quaternary alluvium. Lithologic interpretations of some of the deeper units are based on well log characteristics. Lithologies of the Upper Cretaceous units, above the base of the Austin Group, and the Tertiary units were determined from descriptions of cuttings from LSU Hydrologic Wells R-1A, R-2B, and R-3B and from LETCo's Area Characterization Boring LRH-13. For some units, no near-dome lithologic



CONTOUR INTERVAL = 20 FEET

BASE FROM U.S. GEOLOGICAL SURVEY 1:62,500 QUADRANGLES.

NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
LINEAMENT MAP

JOB NO. MV9600

FIGURE 10-27

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED [illegible] DATE [illegible]
REVISED TMP DATE 12/12/80
REVISED DJ DATE [illegible]
APPROVED GHE DATE 12/23/80

T-1388-2

FIGURE 10-27

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information was available. In such cases, reference is made to Section 9.2.2 for the general lithologic description typical of the unit throughout the study area.

10.2.2.2.1 Cretaceous System, Comanchean Series -

10.2.2.2.1.1 Trinity Stage/Group: The Mooringsport Member of the Rusk Formation is less sandy and the limestones are more massive at Rayburn's than elsewhere in the study area. Although sand deposition was typical of the study area, the dominance of precipitated calcium carbonate may have been due to topographic influence restricting circulation around the Dome.

The lithology of the Greenwood member of the Rusk Formation does not differ from that described for the study area in Section 9.2.2.

10.2.2.2.1.2 Fredericksburg Stage/Group: The lithology of the Paluxy Formation at Rayburn's Dome is essentially the same as that described for the study area in Section 9.2.2. The Goodland Formation has been removed by erosion along the unconformity at the top of the Commanchean in the vicinity of Rayburn's Dome.

10.2.2.2.1.3 Washita Stage/Group: The units of the Washita Stage/Group have been eroded along the unconformity at Rayburn's Dome.

10.2.2.2.2 Cretaceous System, Gulfian Series-

10.2.2.2.2.1 Woodbine Stage, Tuscaloosa Group: The Lower, Middle, and Upper Tuscaloosa Formations are all present at Rayburn's Dome, as they are over much of the Lake Bistineau Structural Bridge and adjoining parts of the Minden and Winnfield Basins. The Lower Tuscaloosa, which is composed predominantly of sands, contains more pyrite and glauconite in the Rayburn's area than elsewhere in the study area, indicating a more restricted marine, reducing environment. Middle Tuscaloosa shales are more calcareous at Rayburn's than elsewhere, indicating deposition in a shallower and/or warmer area of the sea, or in an area of restricted circulation. The lithology of the Upper Tuscaloosa Formation at Rayburn's does not differ greatly from the typical lithology elsewhere in the study area.

10.2.2.2.2.2 Eagle Ford Stage/Group: The lithology of the Eagle Ford Formation does not differ from that described for the study area in Section 9.2.2.

10.2.2.2.2.3 Austin Stage/Group: The Tokio Formation at Rayburn's Dome consists of the same basal chalk, with an overlying shale unit, as elsewhere in the study area. It does not contain the characteristic upper sands, however, and the shales are more micaceous and less calcareous, indicating a deepening of the sea during deposition in the area near the Dome. The Tokio thickens concentrically to the southwest of the Dome, indicating a possible rim syncline (Reese, 1977). The Brownstown Formation throughout the Winnfield Basin usually consists of dark, basin shales. However, at Rayburn's Dome, although the lithology is basically shale, it is calcareous and sandy in the middle interval and at the top, indicating that by the time the Brownstown was being deposited the Dome was topographically higher than during Tokio deposition.

10.2.2.2.2.4 Taylor Stage/Group: The Ozan Formation, which is predominantly marl with thin beds of siltstone and chalk throughout the study area, becomes much less silty at Rayburn's, where it is composed almost entirely of argillaceous chalks and chalky limestones. This indicates that the water was shallower over the dome during deposition, or more restricted in circulation than elsewhere in the study area. The Ozan is upwarped over the dome. A rim syncline to the east is mapped on the base of the Annona Formation (Figure 10-28). The lithology of the Annona Formation does not differ from that of the study area as described in Section 9.2.2.

At Rayburn's Dome, the Marlbrook Formation consists of marly, fossiliferous shales (Echols, 1965). This lithology does not vary greatly from that of the study area. Spooner (1926), however, described a fine-grain white chalk at the top of the Marlbrook, indicating that the formation at Rayburn's is more calcareous than elsewhere in the study area. No disseminated carbonaceous matter or pyrite crystals were found, suggesting that the depositional environment at Rayburn's was not a reducing one. However, shallow water and restricted circulation are indicated by the high calcium carbonate content.

10.2.2.2.2.5 Navarro Stage/Group: The Saratoga Formation at Rayburn's Dome does not differ lithologically from the unit elsewhere in the study area.

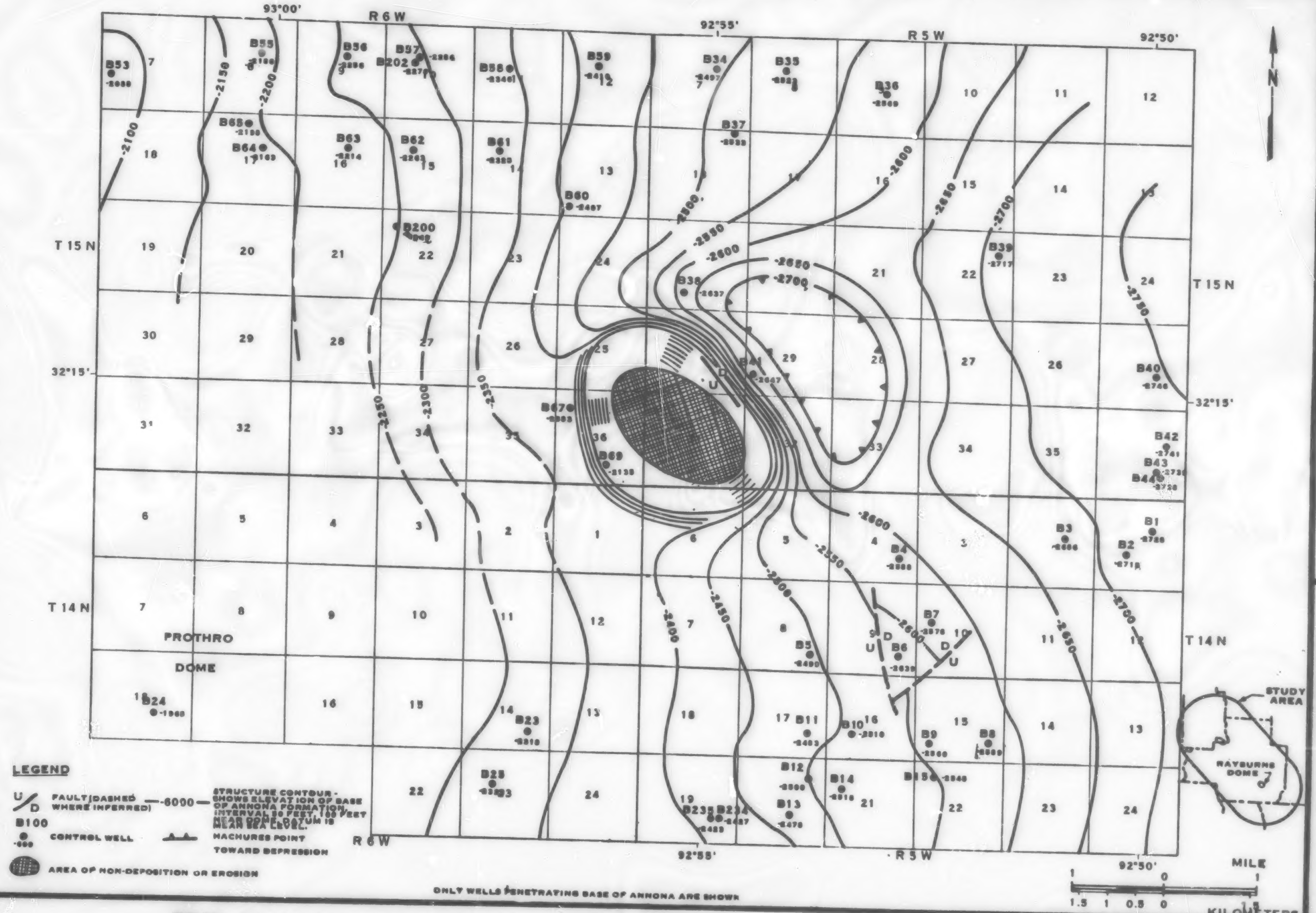
The Nacatoch Formation, however, is more calcareous and less sandy at Rayburn's than elsewhere (See Section 9.2.2). It consists of a white to gray fossiliferous chalk. Dips are gentle from west to east across the domal area, and do not seem to have been affected by a topographic prominence.

The Arkadelphia Formation at Rayburn's Dome is a white to light gray, fossiliferous chalk with thin, calcareous sandstone interbeds. The lithology of the formation varies so much throughout the study area that it is difficult to characterize the Arkadelphia at Rayburn's as typical.

10.2.2.2.3 Tertiary System, Paleocene and Eocene Series -

10.2.2.2.3.1 Midway Stage/Group: The Midway at Rayburn's Dome consists of a sequence of clastic deposits, including clays, shales, and sands. The clays are light gray to dark gray to brownish-gray and are in some places silty or sandy, calcareous, micaceous, locally glauconitic and pyritic. The clays are sometimes indurated to shales. Thin beds of sand and lignite are often present in the upper part of the Midway, making it difficult to distinguish from the lowermost, overlying Wilcox beds.

10.2.2.2.3.2 Wilcox Stage/Group: At Rayburn's Dome the Wilcox is composed of silts, sands, shales, clays, lignite, and



NORTH LOUISIANA STUDY AREA

RAYBURNS DOME
STRUCTURAL CONTOUR MAP
BASE OF ANNONA FORMATION

JOB NO. MV9600

FIGURE 10-28

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED Gmy DATE 12/3/80
REVISED TMJC DATE 12/18/80
REVISED DGP DATE 11/10/81
APPROVED GHE DATE 12/23/80

T-1393-2

FIGURE 10-28

BEST DOCUMENT AVAILABLE

limestone concretions. The sands vary in color from light gray to tan to dark brown and black, and are micaceous, clayey, lignitic, pyritic, and calcareous, often containing disseminated carbonaceous matter. The shales are gray to black, sandy, and pyritic. The clays are vari colored: yellow, blue, brown, gray, red, and black. They contain silt, lignite, sand, organic material, mica, and glauconite. Limestone concretions are light gray to grayish-brown or olive green; locally, they are very finely crystalline, glauconitic, and sandy. The limestone is dolomitic in places. Since there is so much lithologic variation in this group and so much disseminated secondary material, it is difficult to determine if there is significance to lithologic differences between the Wilcox at Rayburn's and in the remainder of the study area.

10.2.2.2.3.3 Claiborne Stage/Group: The Carrizo Formation is not recognized at Rayburn's Dome. (See Section 9.2.2 for discussion of Carrizo deposition.)

The Cane River Formation is present in the domal area and is composed of red, yellow, green-gray, and brown clays which are micaceous, glauconitic, silty, calcareous, and pyritic. Siltstone beds and thin gypsum zones are sometimes present. The clays are so calcareous in places that they are described as marlstones. These marlstones are locally very glauconitic or fossiliferous and have interbedded dolomite and siltstone. Cane River lithology at Rayburn's Dome does not differ from the lithology elsewhere in the study area.

The Sparta consists of sands with a few thin beds of white to gray or brown clay which is sometimes silty or sandy. Lignite strata are sometimes present in the clay. The sands vary in color from colorless to olive gray, gray-reddish-brown, or brown, and contain small amounts of mica, ironstone, glauconite, and pyrite.

The Cook Mountain and Cockfield Formations are not present at Rayburn's Dome, due either to erosion or nondeposition.

10.2.2.2.4 Quaternary System: Lithologies of the Quaternary terraces and alluvium at Rayburns are similar to those elsewhere in the study area, as described in Section 9.2.2 and elaborated on in Section 10.2.2.1. In general, the terraces consist of fluvial sequences of gravel, sand, silt, and clay, with the gravel generally at the base, grading upward into finer materials. A layer thought to be equivalent to the (youngest) Prairie Terrace has been found in a pit excavated over the approximate center of Rayburn's Dome. It is composed of calcite cobbles and boulders, and is overlain by chert, ironstone, and calcite gravel, silt, and oxidized sands.

Overlying this terrace unit are three units assigned to the Quaternary alluvium. The first unit consists of gray sands and massive clays with sand stringers, and an interbedded organic layer of logs and sticks thought to have been deposited 14,000 years before present (B.P.). Overlying this is a unit of gray sands; sandy, silty clays, and massive, gray clays. This unit is thought to be approximately 7,000 years old. The uppermost unit is late Holocene to present-day and is composed of ash gray, massive silts and silty, fine sands.

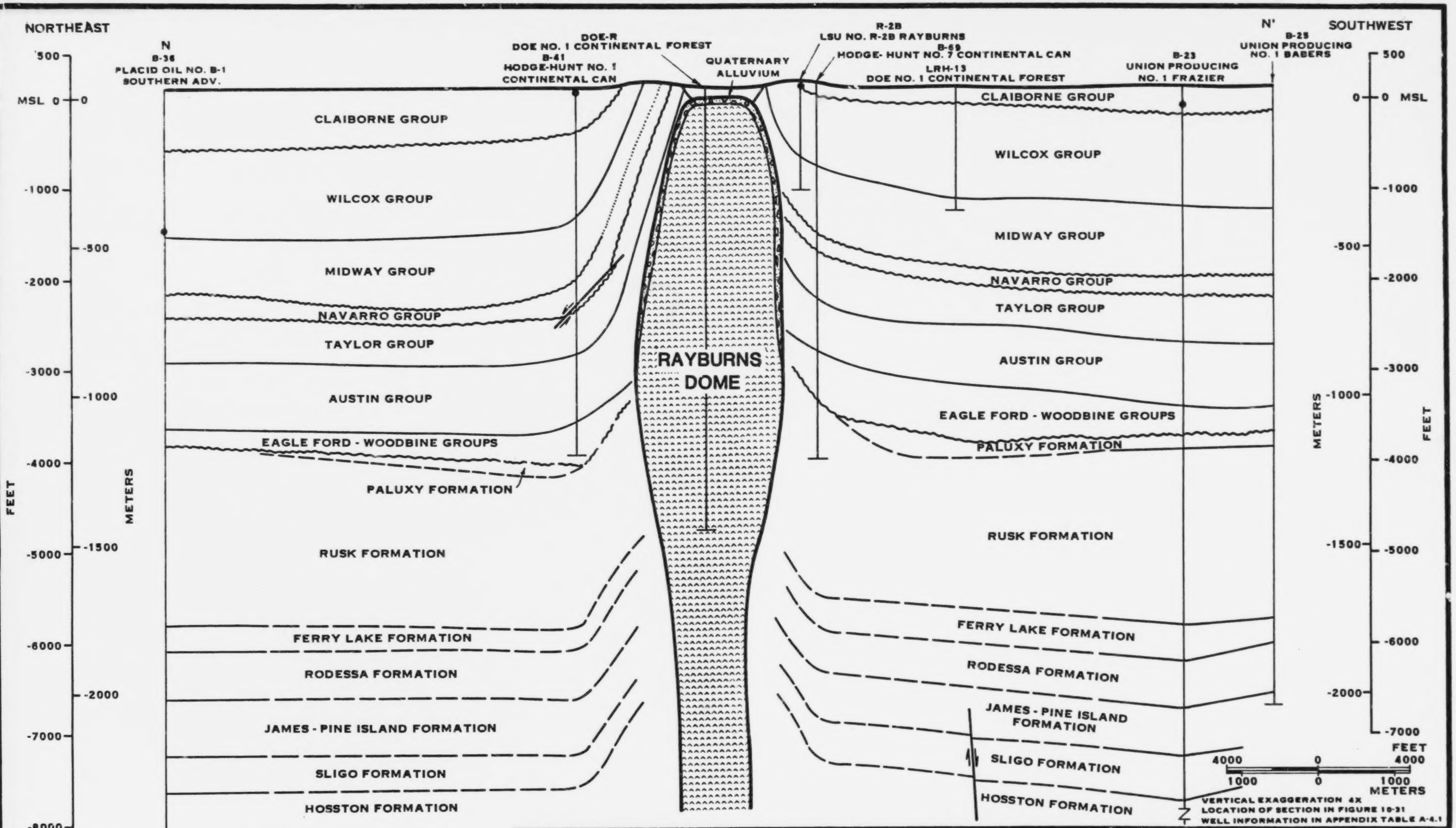
10.2.2.3 Structure: Rayburn's Dome is located in the northeastern portion of the Prothro Syncline. The syncline is bounded by four structural highs: Lucky Arch to the northwest, Topy Creek Arch to the west, Jonesboro Ridge to the south, and Danville High to the east (Figure 9-7). Substantial well control defines the structural highs, but subsurface information is sparse within Prothro Syncline (Figure 10-20). (See Section 9.2.3.2.1.11 for a description of Prothro Syncline.)

The salt-withdrawal basin for Rayburn's Dome, at the time of its most active growth (Early Cretaceous), was elliptical with the long axes oriented northeast-southwest. The dimensions of the basin cannot be determined precisely because of the lack of deep well control southwest of the dome. Dips from the structural highs into the basin are mild, at most 2 degrees on Lower Cretaceous formations (Reese, 1977) and even less on Upper Cretaceous and Tertiary formations (Figures 10-29 and 10-30). (The locations of the geologic sections are shown in Figure 10-31.

The greatest change in thickness from the highs to the basin occurs in Lower Cretaceous units, as shown on the Rodessa, James, and Pine Island isopach contour map (Figure 10-32). A rim syncline developed on the northeast side of Rayburn's Dome by the time of upper Coahuilan deposition (Figure 10-33) and, as interpreted on the Ferry Lake structural contour map (Figure 10-34), continued to be a prominent structural feature at least through the lower Trinity Stage. Rim synclinal development southwest of Rayburn's and northeast of Prothro Dome is difficult to determine due to a lack of deep well control, but seismic data in this area indicates that very little development occurred. Maximum rim synclinal development and, therefore, maximum growth of Rayburn's Dome probably occurred during deposition of the James Formation (Reese, 1977). Thereafter, the rim syncline decreased in size, indicating a decreasing rate of growth since the Early Cretaceous.

Activity within the Prothro Syncline during the Late Cretaceous occurred primarily to the southwest around Prothro Dome, although some activity did occur near Rayburn's Dome during early Gulfian time (Reese, 1977). Well data for the base of the Annona Formation (Figure 10-28) and the top of the Nacatoch Formation (Figure 10-35) suggest that a remnant of the syncline on the northeast side of Rayburn's Dome may have been present through the Cretaceous.

Structural development during the Tertiary Period is difficult to evaluate due to lack of well control. The attitude of the Tertiary surface near Rayburn's, except adjacent to the dome, is dominantly controlled by the regional eastward dip (Figure 10-36). Minor thickening of the Midway Group surrounding Rayburn's Dome (Figure 10-37) indicates that the rim syncline that was prominent during the Early Cretaceous was still subsiding and receiving sediments during the Late Cretaceous and early Tertiary.



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GEOLOGIC EVALUATION GULF COAST SALT DOMES
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NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
GEOLOGIC SECTION N - N'

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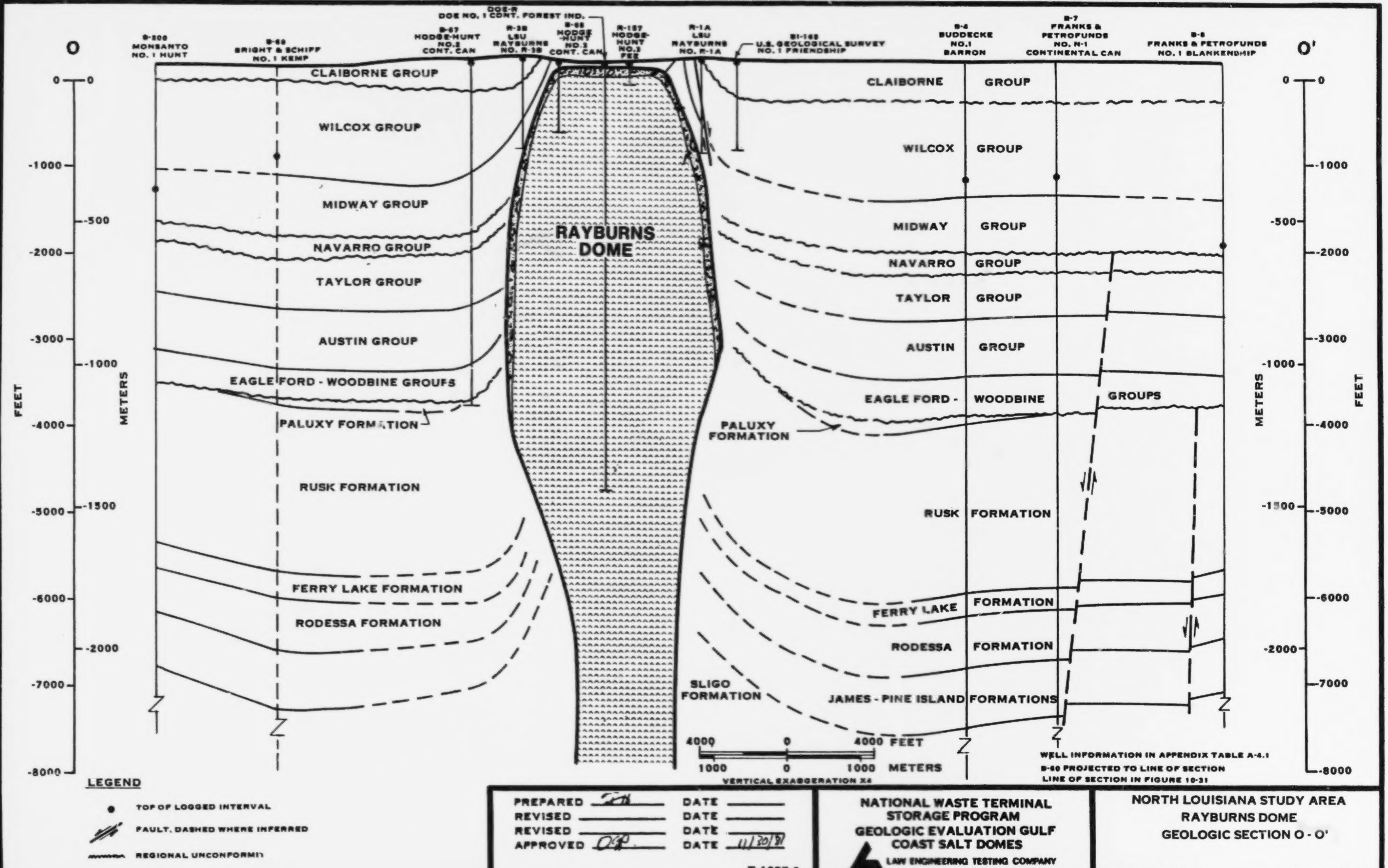
FIGURE 10-29



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NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
GEOLOGIC SECTION O - O'

JOB NO. MV9600

FIGURE 10-30

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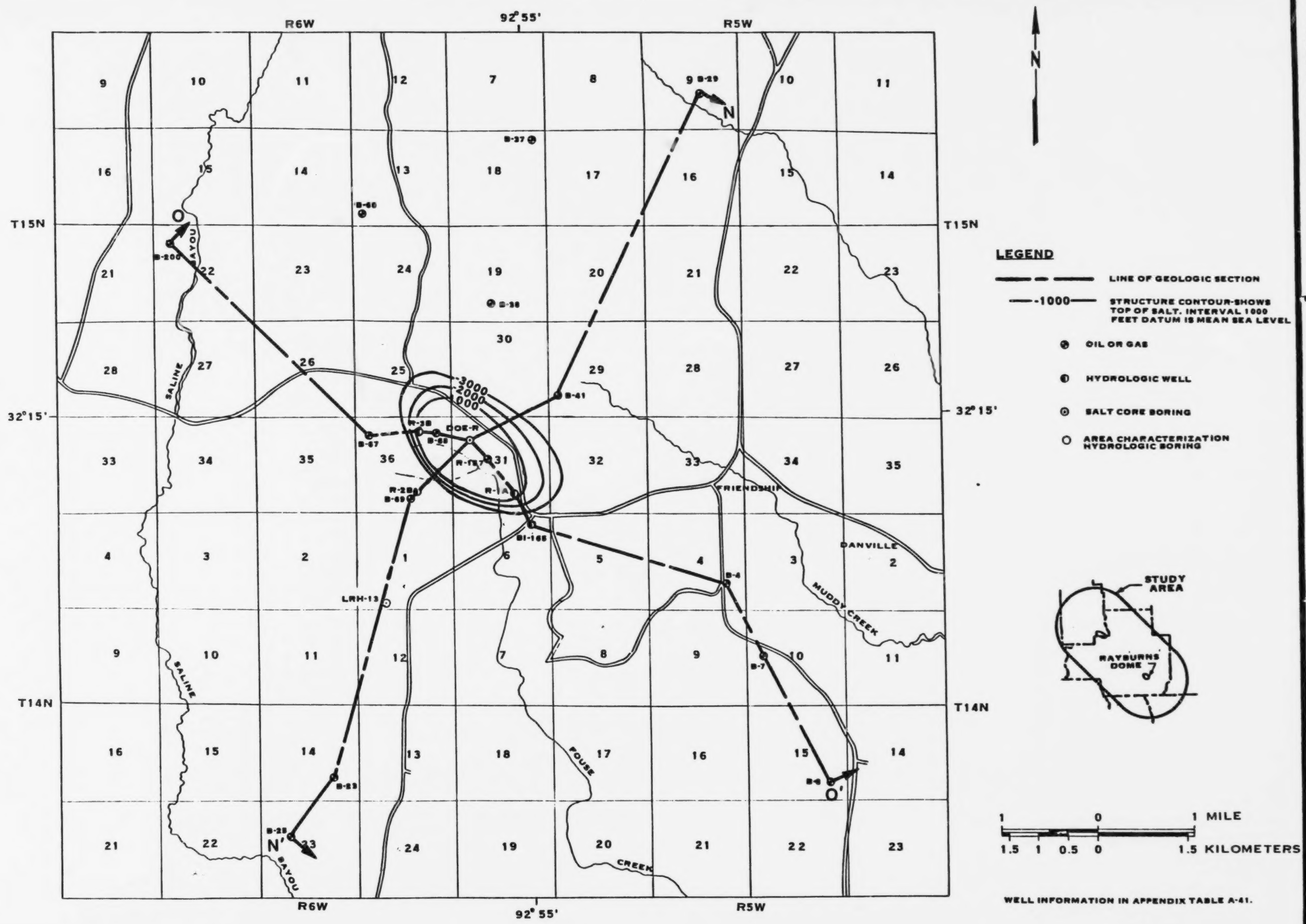

LEGEND

LINE OF GEOLOGIC SECTION

-1000 STRUCTURE CONTOUR-SHOWS TOP OF SALT. INTERVAL 1000 FEET DATUM IS MEAN SEA LEVEL

● OIL OR GAS

◐ HYDROLOGIC WELL

⊙ SALT CORE BORING

○ AREA CHARACTERIZATION HYDROLOGIC BORING

WELL INFORMATION IN APPENDIX TABLE A-41.

NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
LOCATION OF GEOLOGIC SECTIONS
N - N' AND O - O'

FIGURE 10-31

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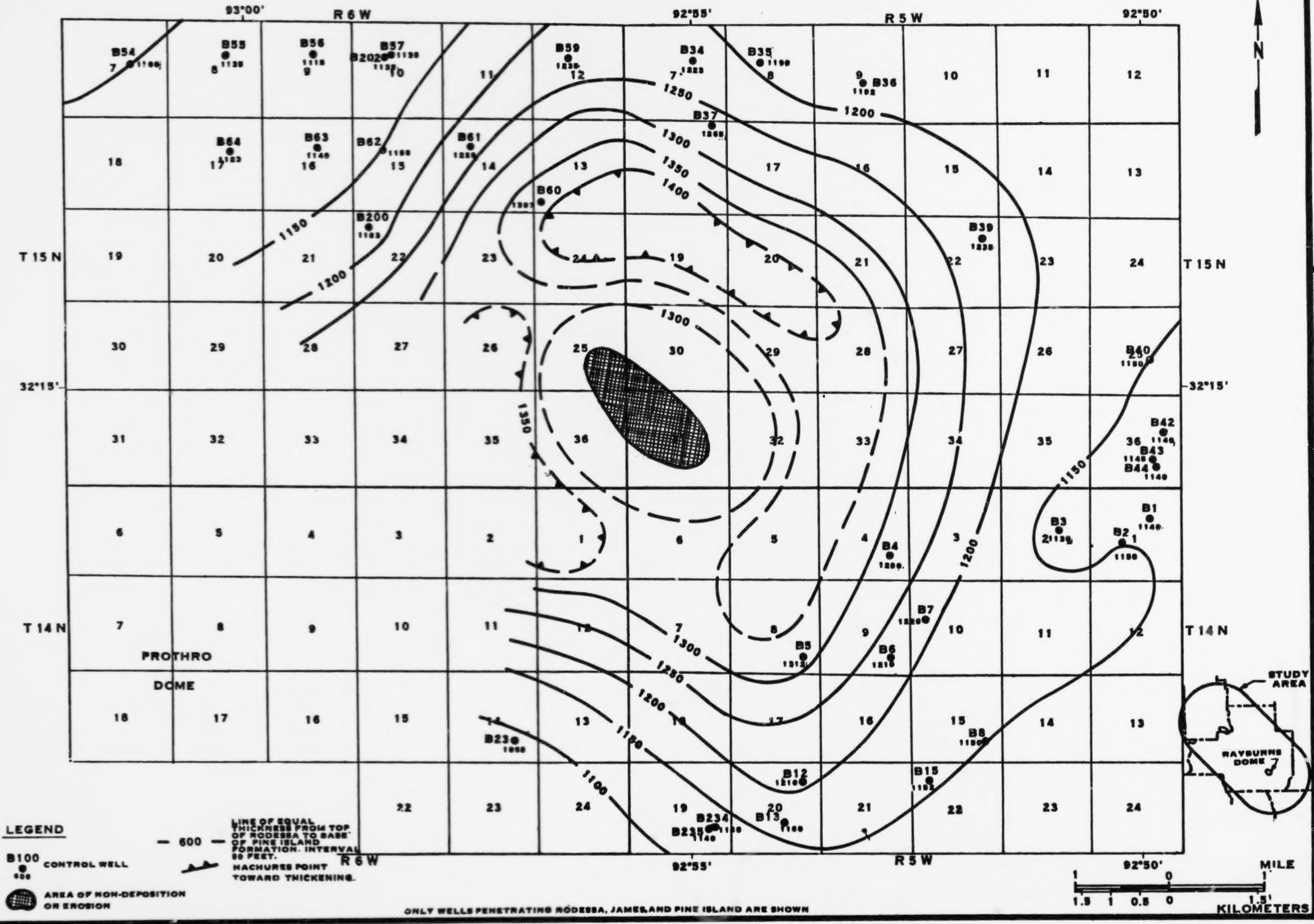
FIGURE 10-31 [redacted]



LEGEND

B100 ● 600 CONTROL WELL

— 600 — LINE OF EQUAL THICKNESS FROM TOP OF RODESSA TO BASE OF PINE ISLAND FORMATION. INTERVAL 50 FEET.

HACHURES POINT TOWARD THICKENING.

AREA OF NON-DEPOSITION OR EROSION

ONLY WELLS PENETRATING RODESSA, JAMES, AND PINE ISLAND ARE SHOWN

NORTH LOUISIANA STUDY AREA

RAYBURNS DOME
ISOPACHOUS CONTOUR MAP OF
RODESSA, JAMES, AND
PINE ISLAND FORMATIONS

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FIGURE 10-32

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COAST SALT DOMES

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FIGURE 10-32

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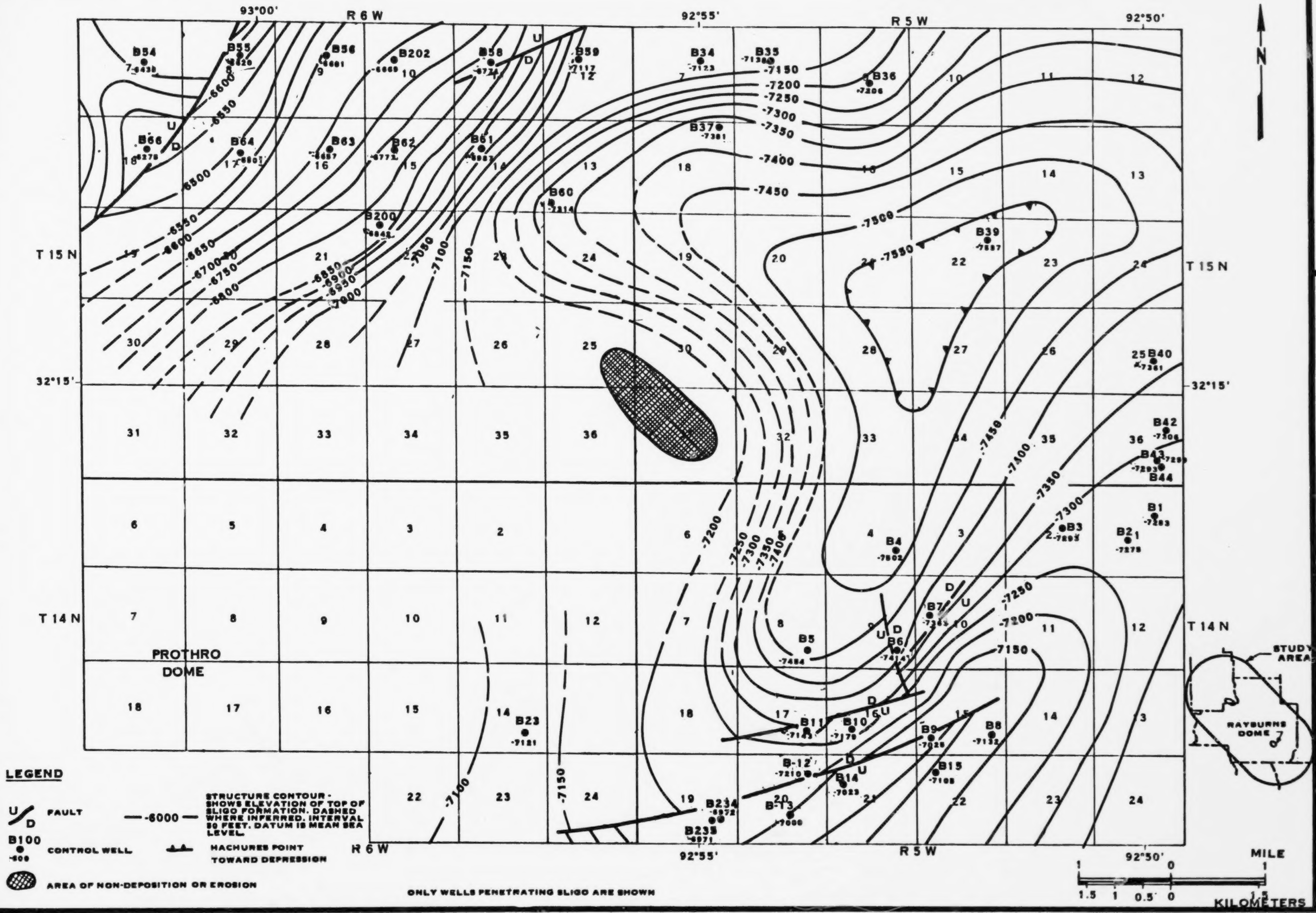

NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
STRUCTURAL CONTOUR MAP
TOP OF SLIGO FORMATION

JOB NO. MV9600 FIGURE 10-33

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GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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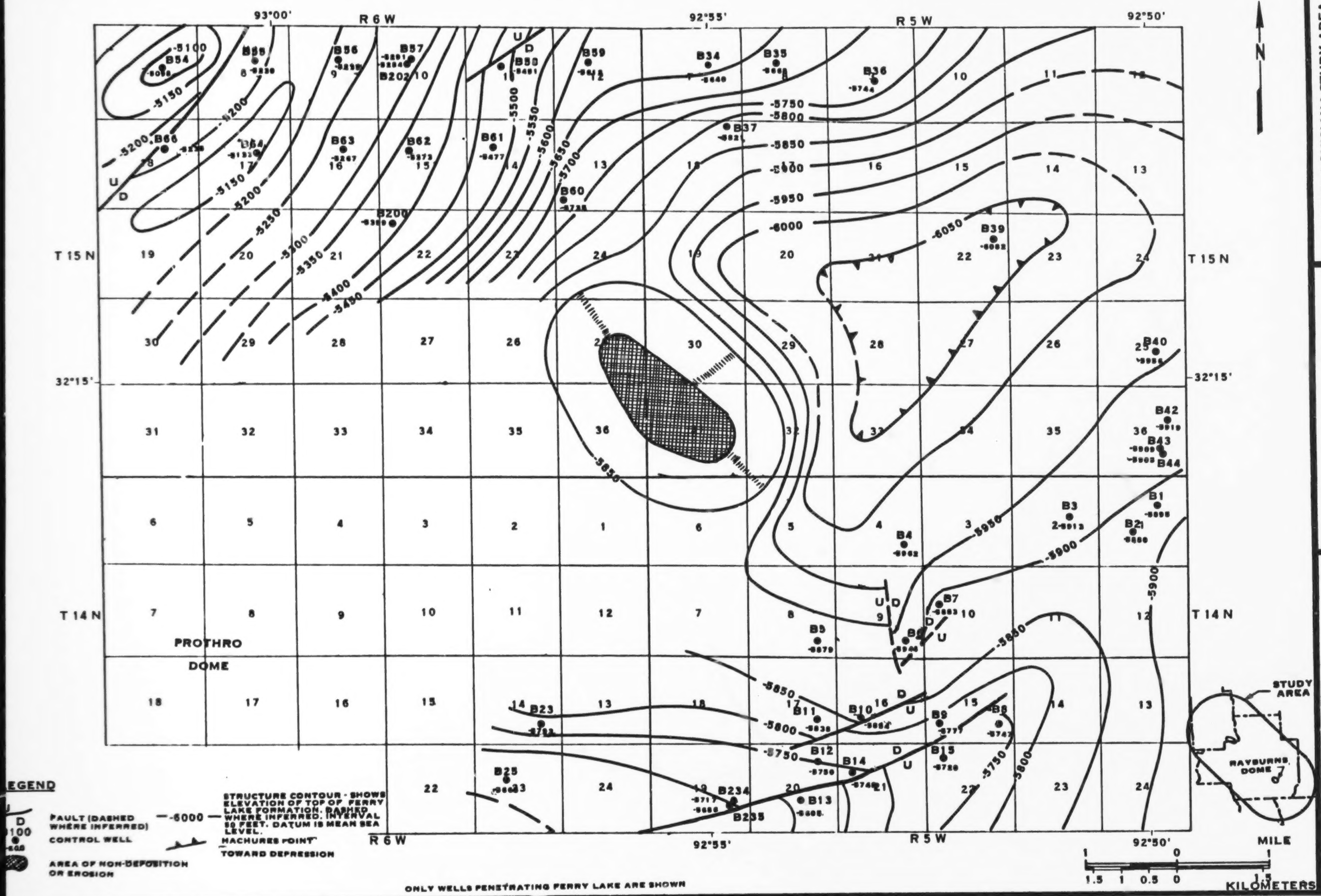
FIGURE 10-33



NORTH LOUISIANA STUDY AREA
RAYBURNS DOME
STRUCTURAL CONTOUR MAP
TOP OF FERRY LAKE FORMATION

FIGURE 10-34

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FIGURE 10-34

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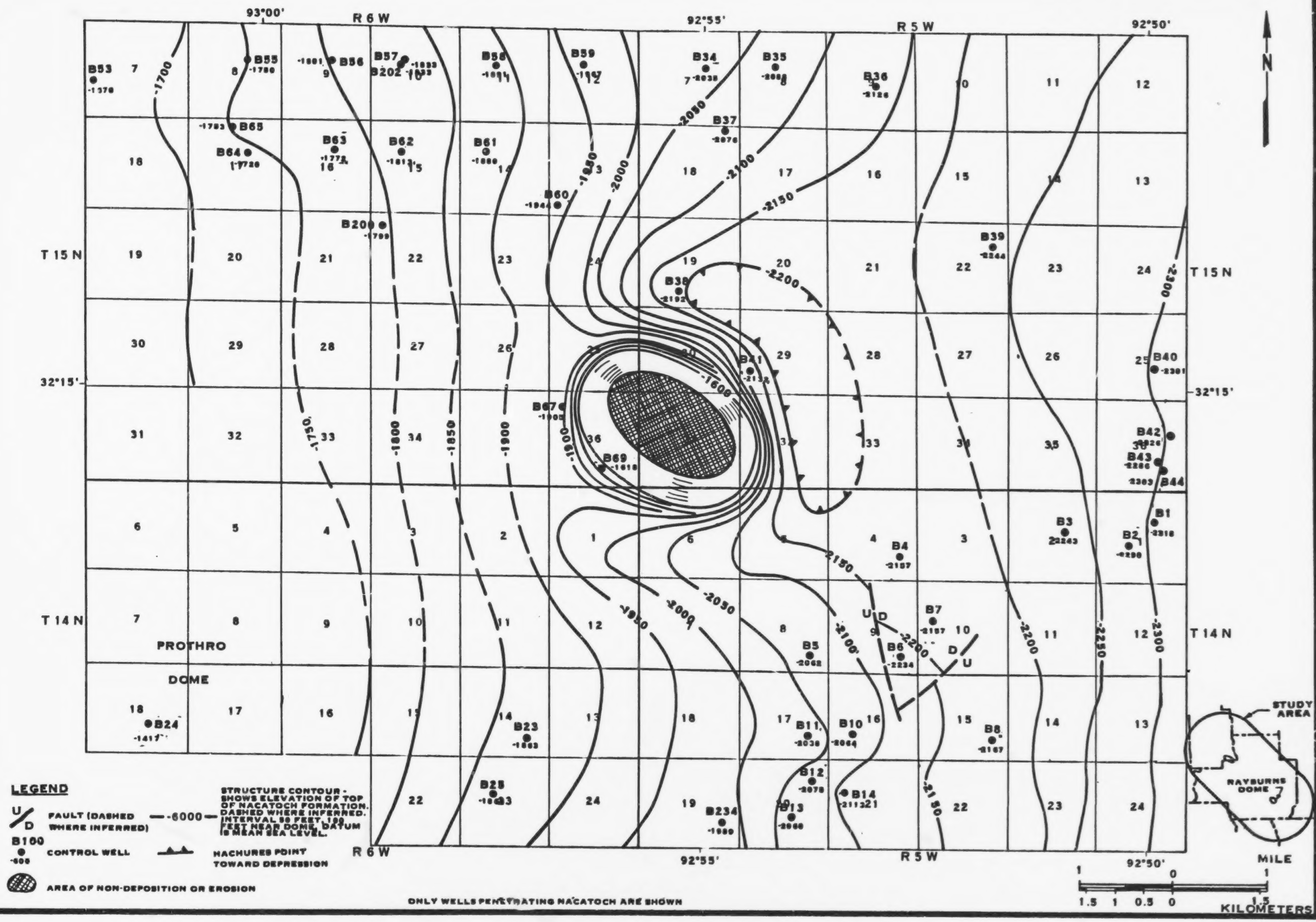

NORTH LOUISIANA STUDY AREA

RAYBURNS DOME
STRUCTURAL CONTOUR MAP
TOP OF NACATOCH FORMATION

JOB NO. MV9600 FIGURE 10-35

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COAST SALT DOMES

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FIGURE 10-35

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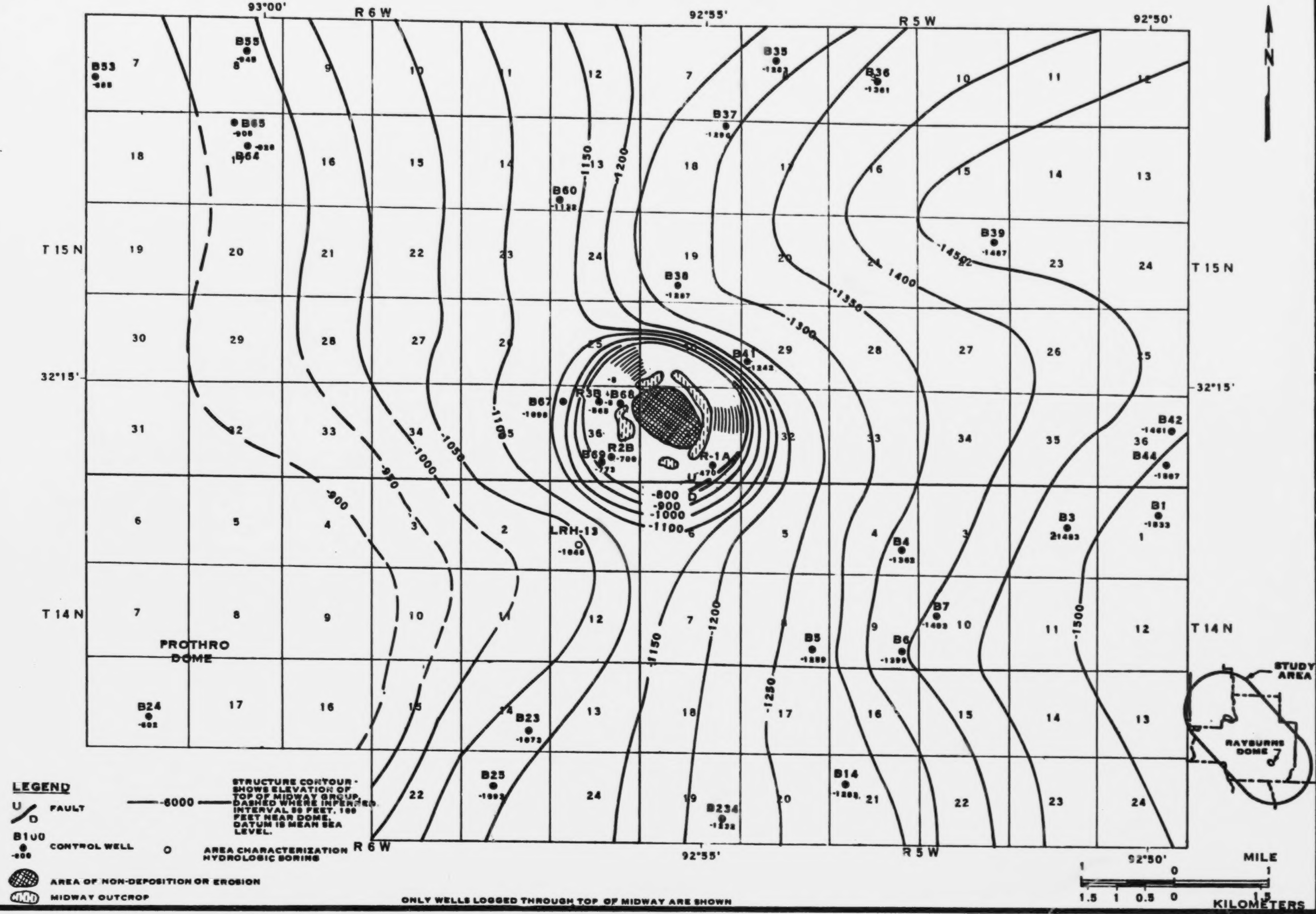

NORTH LOUISIANA STUDY AREA

RAYBURNS DOME
STRUCTURAL CONTOUR MAP
TOP OF MIDWAY GROUP

JOB NO. MV9600

FIGURE 10-36

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 10-36

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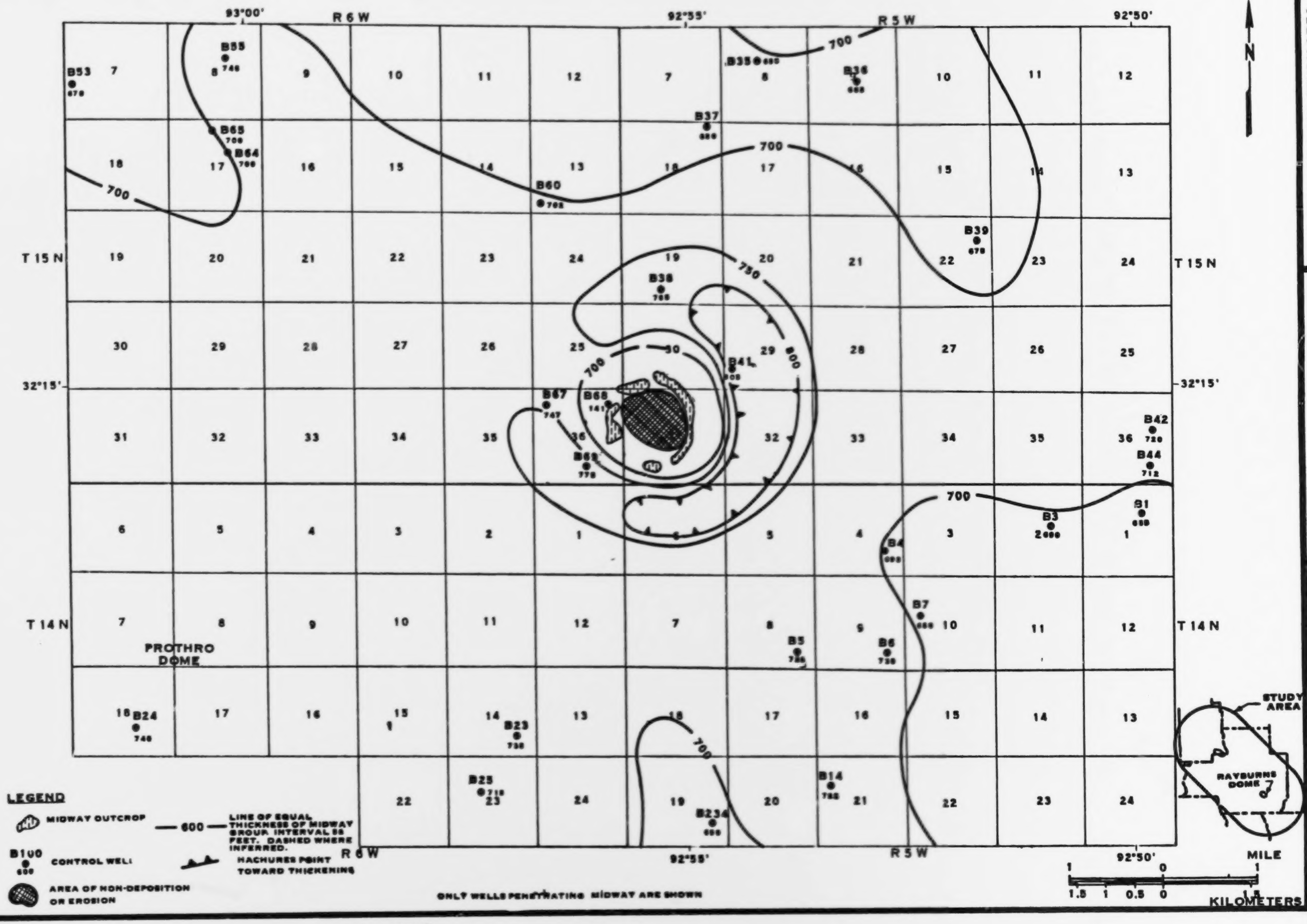

NORTH LOUISIANA STUDY AREA

RAYBURNS DOME
ISOPACHOUS CONTOUR MAP
OF MIDWAY GROUP

JOB NO. MV9600 FIGURE 10-37

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 10-37

[redacted]

The structure adjacent to and overlying the dome is not well known due to lack of well control. Available information indicates steeply dipping beds (near vertical) on the domal flanks and only thick Quaternary alluvium over the central part of the dome (Figures 10-29 and 10-30). Upper Cretaceous outcrops on the east and northeast flanks (Figure 10-26) indicate faulting and uplift of the flanking sediments.

Although only two faults have been mapped on the east flank of Rayburn's, faulting probably occurs on all sides of the dome. Kumar (1977) interprets a normal, up-to-the-dome fault cutting the LSU Hydrologic Well R-1A (Figure 10-30). This interpretation is based on an abrupt change in dip within the Wilcox Group indicated on the dipmeter log. A deeper, up-to-the-dome normal fault is inferred from what appears to be a repeated section of the Saratoga Formation in the Hodge-Hunt Lumber Co #1 Continental Can Well B-41 (Figure 10-29). It is interpreted as a normal fault because reverse faults are rarely expected to occur in association with salt domes (Murray, 1961). The youngest interpreted faulting associated with Rayburn's Dome can only be determined to have occurred after the early Eocene (after deposition of the Wilcox Group) because late Eocene and younger Tertiary sediments have been eroded.

Remote sensing studies have detected lineaments in Tertiary and Quaternary sediments above and flanking Rayburn's Dome that may or may not be related to faulting (Figure 10-27). The four, short, USDA-photo lineaments radiating from the center of the dome particularly suggest the possibility of faults related to domal growth.

10.2.3 MINERAL RESOURCES: Potential mineral resources at Rayburn's Dome include sand, gravel, salt, gypsum, anhydrite, limestone, lignite, agricultural lime, oil, and gas.

10.2.3.1 Sand and Gravel: Sand and gravel are present in Quaternary deposits in the central depression over Rayburn's Dome and in stream valleys in the vicinity of the dome. Sand occurs in the unconsolidated Sparta Formation. No large sand and gravel operations are known to exist in the area; however, Continental Forest Industries extracts small amounts of aggregate from their property on the north flank of Rayburn's Dome to use for logging road metal.

10.2.3.2 Salt: Although salt and brine have been produced at Rayburn's Dome in the past, they are not currently being extracted. During the Civil War salt water was pumped from shallow wells 3 to 6 meters (10 to 20 ft) deep and evaporated in large kettles to produce salt, a scarce and valuable commodity to the Confederacy. In the early 1920's Southern Bag and Advance Company drilled several wells into the salt, about 76 meters (250 ft) deep, to obtain brine for their paper bleaching operation. Brine was produced until early in 1943 (Meade, 1980). Future salt production is feasible at Rayburn's by conventional mining methods or by brining due to the shallow depth to salt (less than 61 meters (200 ft).

10.2.3.3 Gypsum and Anhydrite: Gypsum, anhydrite, and limestone are present in the caprock of Rayburn's Dome at depths of less than 30 meters (100 ft). The T. L. James Company recently attempted to quarry the caprock or the limestone boulder zone, interpreted by Kolb (1977, 1978, 1979) to overlie the caprock, for use as aggregate. A test pit, approximately 40 to 46 meters (130 to 150 ft) long, 12 to 15 meters (40 to 50 ft) wide, and 2 to 12 meters (8 to 40 ft) deep, uncovered several boulders (Martinez and others, 1980). The depth to minable limestone as well as an uncontrollable flow of saline ground water caused the operation to be abandoned.

10.2.3.4 Lignite: Lignite occurs at Rayburn's Dome in the Wilcox Group and to a lesser extent in the Sparta Formation. A 3-meter (10-ft) bed of lignite and lignitic silts was penetrated by a Louisiana State University hydrologic well (R-1A) at a depth of 6 meters (20 ft) on the south flank of the dome (Martinez and others, 1978). The economic importance of this or other lignitic deposits at Rayburn's is unevaluated. Thicker, shallower, lignitic seams of known grade are present in DeSoto and Sabine Parishes.

10.2.3.5 Agricultural Lime: Cretaceous limestone outcrops on the east side of Rayburn's Dome were quarried from 1943 through

1945 to produce agricultural lime. The lime was not of hig quality and the operation was unprofitable. The low quality o the lime and the limited areal extent of the source rock wil probably preclude future quarrying.

10.2.3.6 Oil and Gas: Rayburn's Dome is surrounded by four oi and gas fields: Liberty Hill, Lucky, Saline, and Danvill (Figure 9-29). The production closest to the dome is about 3 k (1.8 mi) to the southeast. Six wells have been drilled on th flanks of the dome with no resulting production. None of th wells, however, have tested the deeper producing horizon (Rodessa, Sligo, Hosston, Cotton Valley), nor penetrated the sal overhang interpreted from gravity data. The probability o finding economically productive reservoirs of oil or gas a Rayburn's Dome is considered low (Murray, 1979).

10.3 SUMMARY OF SELECTED DOMES

The geologic characterization of Vacherie and Rayburn's Domes focused on the areas within a 8-km (5-mi) radius of the domes. Land access problems have hampered collection of high-resolutio seismic data and reduced the extent of ground-level resistivity surveys.

The two candidate domes were modeled by computer, using both gravity and existing well data, to estimate their size and shape. The models were used to calculate the total area at -610,-762, and -914 meters (-2,000, -2,500, and -3,000 ft) MSL. Total area ranges from 822 to 1,104 hectares (2,031 to 2,730 acres) at

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Vacherie, and from 319 to 438 hectares (790 to 1,082 acres) at Rayburn's.

Available surface and subsurface geologic data were evaluated to determine the growth history of the domes and their present condition of stability. From these studies it appears that the domes became stable during the mid-to-late Tertiary. Preliminary studies of Quaternary terraces at Vacherie indicate no evidence of structural movement during the past 300,000 to 500,000 years.

The subject of mineral resources was evaluated by analysis of published data, purchased data, and special reports. An assessment of potential mineral reserves over, and in proximity to, the candidate domes compared them according to known or potentially economic deposits which would become unproduceable due to construction of a repository. Although petroleum exploration has not been extensive enough at Vacherie or Rayburn's to assure that they are barren, neither dome is considered likely to yield significant quantities of oil or gas. Exploitation of rock salt, gypsum, anhydrite, and limestone is more favorable at Rayburn's than at Vacherie Dome because of the shallow depth of burial. However, recent attempts to quarry limestone from the caprock at Rayburn's were unsuccessful due to an uncontrollable flow of saline ground water.

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11 HYDROLOGIC CHARACTERIZATION OF THE NORTH LOUISIANA STUDY AREA

The purpose of this chapter is to discuss the surface and subsurface hydrology of the study area and at selected domes within the study area. This investigation is intended for use as an information base to aid in the selection of specific domes for additional study.

The scope of this chapter includes characterization of the hydrology of the study area with emphasis on the hydrology in the vicinity of Vacherie and Rayburn's Salt Domes. Regional and near-dome surface-water hydrology are described and preliminary analyses of flooding potential from streams at dome sites are presented. Regional and near-dome ground-water hydrology are also described, and preliminary analyses of estimated average ground-water flow times in the subsurface at candidate domes are presented.

The study area, which covers approximately 2,590 km^2 (1,000 mi^2), is located in northern Louisiana (Figure 11-1). The study area is in the Red River watershed.

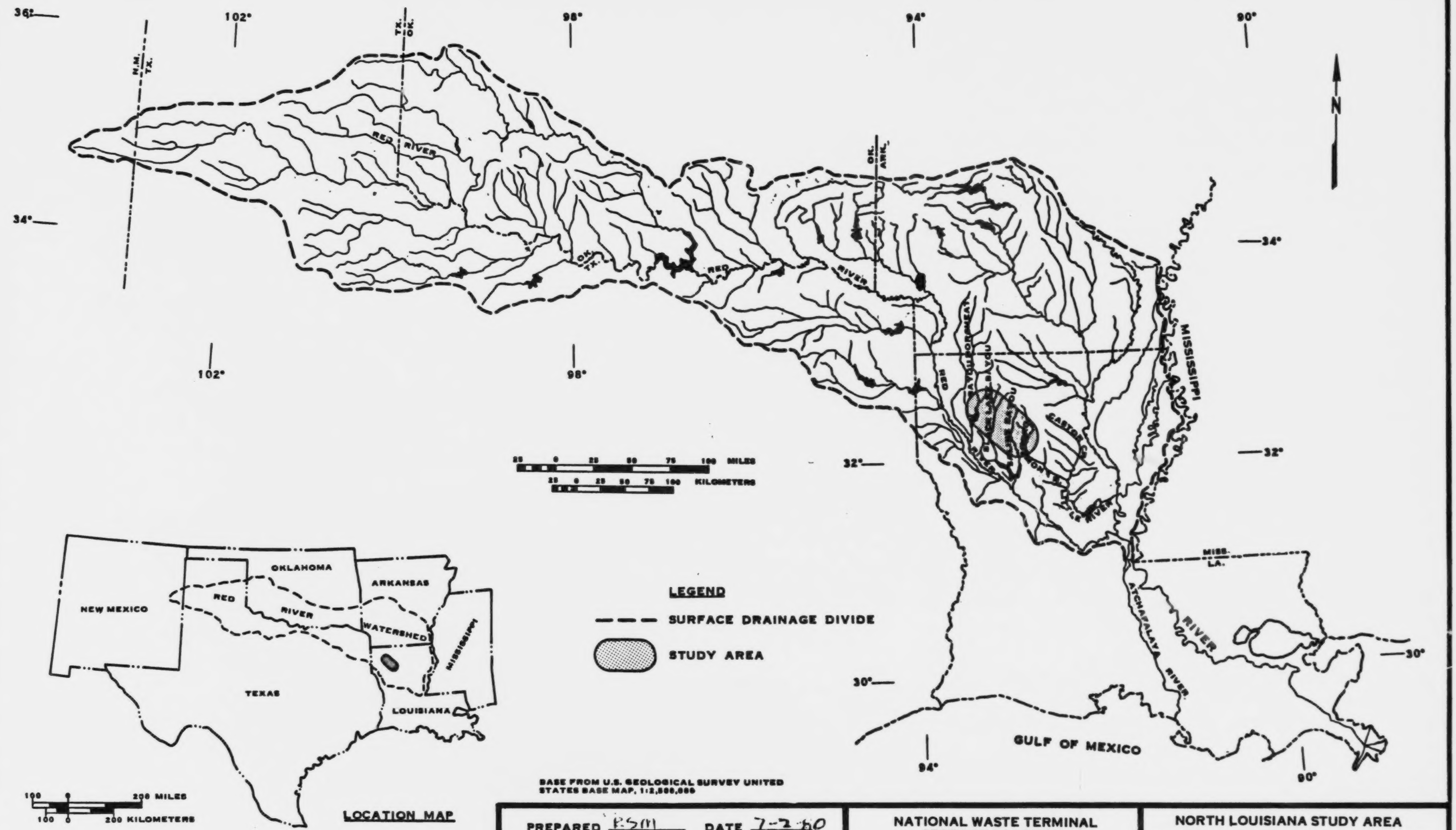
The hydrology of North Louisiana has been described in varying detail in statewide and regional reports. Ground-water level data for Louisiana have been compiled by the U. S. Geological Survey (1975). Rollo (1960) described general ground-water conditions in the state. Winslow and others (1968) have investigated the occurrence of saline water in Louisiana. Municipal water supply data for the state have been compiled by Dial (1970).

Cardwell and Walter (1979) compiled 1975 water use data for Louisiana. Anderson and others (1973) summarized the hydrology in an area that included North Louisiana. Payne (1968, 1970, 1972, 1975) investigated the occurrence and movement of ground water in selected geologic units in North Louisiana. More recently, Hosman (1978) described the regional ground-water hydrology in and around the study area. Additionally, Martinez and others, (1975, 1976, 1977, 1978, 1979) have been studying the tectonic and hydrologic stability of salt domes in the Gulf Coast area.

The Louisiana District Office of the Water Resources Division, USGS, and the Institute of Environmental Studies at Louisiana State University (LSU/IES) are both currently involved in hydrologic investigations that include the study area. The USGS studies are centered on refining the definition of the regional hydrology in North Louisiana. The LSU/IES studies are focused on better definition of the tectonic and hydrologic stability of salt domes in the Gulf Coast area.

11.1 HYDROLOGIC FIELD DATA-COLLECTION PROGRAM

A field program was designed to collect regional as well as near-dome hydrologic data within the study area. The program was designed in consultation with USGS and LSU/IES. This program included five hydrogeologic data-collection sites distributed around the study area, and numerous surface-water chemistry data-collection sites distributed around the candidate domes. The



BASE FROM U.S. GEOLOGICAL SURVEY UNITED STATES BASE MAP, 1:2,500,000

PREPARED	RSM	DATE	7-2-80
REVISED	RSM	DATE	12/26/80
REVISED	Oap	DATE	11/30/81
APPROVED	GHF	DATE	12/30/80

T-1207-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA
RED RIVER WATERSHED MAP SHOWING LOCATION OF STUDY AREA

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FIGURE 11-1

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The locations of sites where hydrogeologic data were collected are shown in Figure 11-2.

Data were collected to meet specific objectives which included:

(1) Defining the vertical location, thickness, and lithology of hydrogeologic units in the study area, and at candidate domes to a depth of approximately -914 meters (-3,000 ft) MSL

(2) Determining hydraulic properties of these hydrogeologic units

(3) Determining general flow directions and rates of travel of the ground water in these hydrogeologic units

(4) Relating chemical composition of ground water in the ground-water reservoir to flow patterns in the reservoir.

11.1.1 SURFACE WATER: No surface-water flow data were collected in the field during this investigation. Information needed for regional and near-dome studies were obtained from published reports, or were computed using standard techniques.

A general description of the geomorphology of the study area is presented in Section 9.2 of this report.

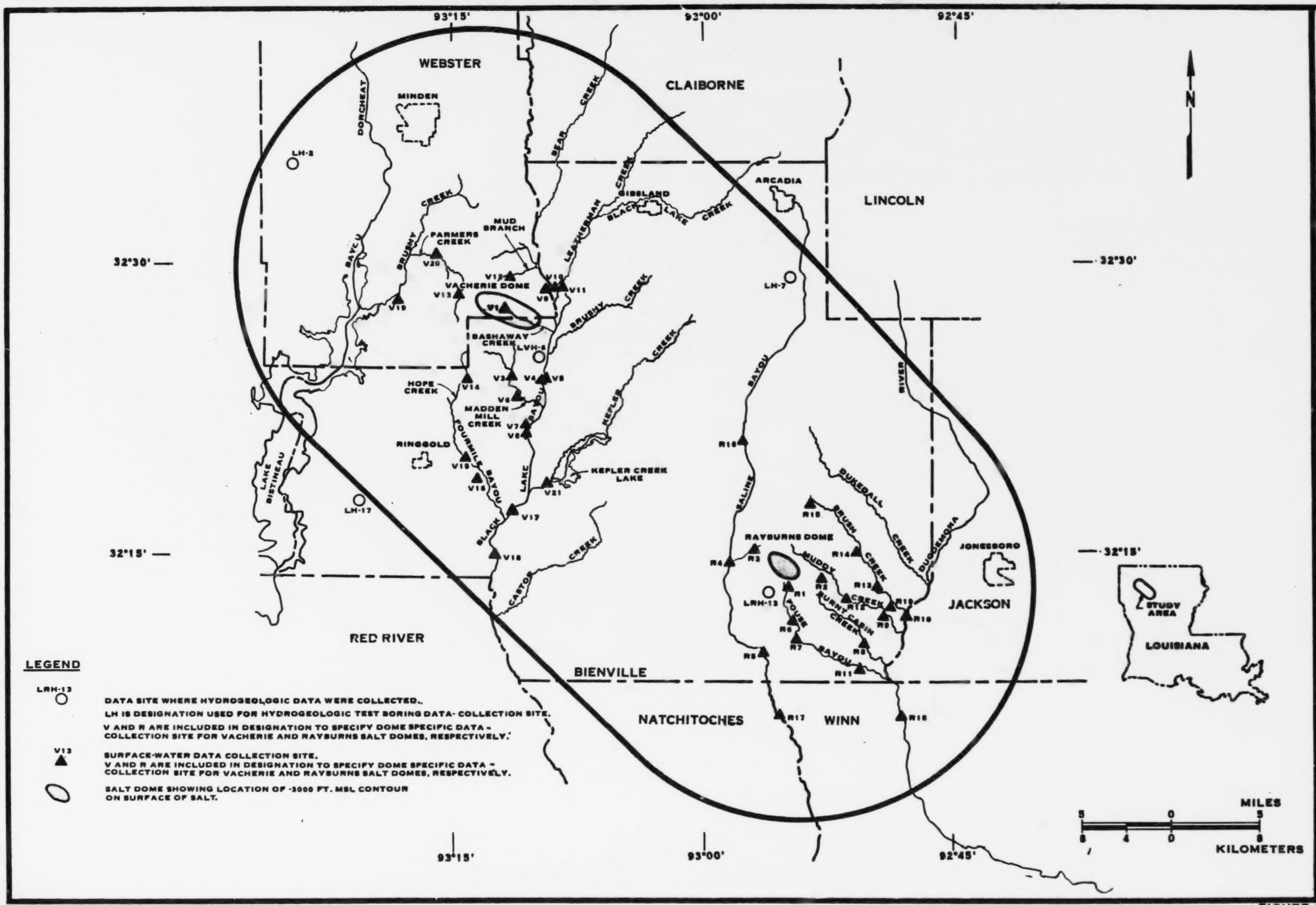
11.1.2 GROUND WATER: Hydrogeologic data-collection sites were chosen to provide a basis for describing the regional hydrogeology in the study area and the hydrogeology at candidate domes. Five sites were selected for collection of hydrogeologic data. Two of these sites were selected for collection of near-dome hydrogeologic data, one each in the vicinity of Vacherie and Rayburn's Domes.

Up to five separate wells were drilled at each site, and each well at a site was completed in a different formation. This made it possible to collect comparable data from a number of hydrogeological units at a site.

Geophysical logs, aquifer tests, and water-level data were collected at each site. Geophysical logs were run to help determine the vertical location, thickness, and lithology of hydrogeologic units at the site. Aquifer tests were conducted to obtain data for computing hydraulic conductivity for hydrogeologic units. Water-level data were collected to aid in defining directions and rates of ground-water movement.

Sidewall cores were taken from selected wells at each hydrogeologic data-collection site. These samples were analyzed for porosity, permeability, grain density, grain-size distribution, and cation exchange capacity.

11.1.3 WATER CHEMISTRY: A program for collecting chemical data was designed to aid in determining the relationship of surface water to ground water, characterization of aquifers, and the directions of ground-water movement. Conductance, pH, dissolved oxygen (DO) and temperature were measured at selected stream locations in the vicinity of the two candidate domes. Water samples were collected from each well at the hydrogeologic data-collection sites. These samples were analyzed for common



LEGEND

LRH-13 ○ DATA SITE WHERE HYDROGEOLOGIC DATA WERE COLLECTED.

LH IS DESIGNATION USED FOR HYDROGEOLOGIC TEST BORING DATA- COLLECTION SITE.

V AND R ARE INCLUDED IN DESIGNATION TO SPECIFY DOME SPECIFIC DATA - COLLECTION SITE FOR VACHERIE AND RAYBURNS SALT DOMES, RESPECTIVELY.

V13 ▲ SURFACE-WATER DATA COLLECTION SITE.

V AND R ARE INCLUDED IN DESIGNATION TO SPECIFY DOME SPECIFIC DATA - COLLECTION SITE FOR VACHERIE AND RAYBURNS SALT DOMES, RESPECTIVELY.

⬭ SALT DOME SHOWING LOCATION OF -3000 FT. MSL CONTOUR ON SURFACE OF SALT.

NORTH LOUISIANA STUDY AREA
REGIONAL DRAINAGE SHOWING
LOCATION OF HYDROLOGIC DATA -
COLLECTION SITES

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FIGURE 11-2

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED RSM DATE [illegible]
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FIGURE 11-2

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elements and selected trace elements. Selected physical properties of the ground water were measured during sample collection.

11.2 REGIONAL HYDROLOGIC CHARACTERIZATION

The hydrology of the study area was defined by integrating data from the literature with data collected in the field. An understanding of the regional hydrology is essential to understanding the hydrology in the vicinity of specific domes.

11.2.1 REGIONAL SURFACE-WATER HYDROLOGY: The Louisiana Study Area is in the southeastern portion of the Red River watershed, the southernmost of the main tributaries of the Mississippi River (Figure 11-1). The Red River has a drainage area of about 240,870 km^2 (93,000 mi^2). Its headwaters are in the High Plains of eastern New Mexico and northwest Texas at an approximate elevation of 1,372 meters (4,500 ft) MSL. The Red River flows in a general southeasterly direction for more than 1,930 km (1,200 mi) to enter the Mississippi River flood plain some 547 km (340 mi) upstream from the Gulf of Mexico.

Bayou Dorcheat, Black Lake Bayou, Saline Bayou, and Dugdemona River drain the study area (Figures 11-1 and 11-2). These streams are tributaries to the Red River.

The discussion of surface-water hydrology for the study area is focused on the Black Lake Bayou and Dugdemona River watersheds. Vacherie Dome is located in the Black Lake Bayou watershed, and Rayburn's Dome is located in the Dugdemona River watershed.

11.2.1.1 Hydrologic Description of Black Lake Bayou Watershed: The headwaters of Black Lake Bayou are approximately 19 km (12 mi) northeast of Minden, Louisiana, in southwestern Claiborne Parish (Figure 11-2). Black Lake Bayou flows almost due south from its headwaters into Black Lake, and its continuation, Clear Lake, before joining Saline Bayou. Saline Bayou is a direct tributary to the Red River. The Black Lake Bayou watershed has a drainage area of 2,351 km^2 (908 mi^2) (Sloss, 1971).

The Black Lake Bayou watershed has a temperate, humid climate. The mean annual temperature over the watershed is 19C (67 F). Mean annual precipitation over the watershed is about 1,346 mm (53 in), and mean annual runoff from the watershed is approximately 432 mm (17 in) (USGS, 1977).

The topography of the Black Lake Bayou watershed varies from flat land to rolling hills. Channel slopes are from 0.4 m/km (2 ft/mi) on the main channel to over 5.6 m/km (30 ft/mi) on the smaller streams. Elevations in the watershed extend from about 122 meters (400 ft) MSL in the headwaters area, to about 30 meters (100 ft) MSL where Black Lake Bayou discharges into Saline Bayou, just upstream from the Red River. Local relief is about 46 meters (150 ft).

The principal tributaries of Black Lake Bayou include Bear Creek, Leatherman Creek, and Grand Bayou.

[redacted]

11.2.1.2 Hydrologic Description of Dugdemona River Watershed: The headwaters of the Dugdemona River are in Lincoln Parish. The Dugdemona River flows generally southeastward to its confluence with Castor Creek to form the Little River (Figure 11-1). The Dugdemona River watershed has a drainage area of 2,424 km^2 (936 mi^2) (Sloss, 1971).

The Dugdemona River watershed has a temperate, humid climate characterized by long, hot summers and short, mild winters. The mean annual temperature in the area of the watershed is about 19 C (66 F). Mean annual precipitation over the watershed is about 1,422 mm (56 in), and mean annual runoff from the watershed is approximately 381 mm (15 in) (USGS, 1977).

The topography of the Dugdemona River watershed is characterized by rounded hills. Maximum topographic relief in the watershed is about 140 meters (460 ft). Driskill Mountain, the highest point in the watershed and also the highest point in the state, is 163 meters (535 ft) MSL. The mountain is located on the watershed's northwest boundary, in Bienville Parish. The lowest point is about 23 meters (75 ft) MSL, where the Dugdemona River and Castor Creek meet to form the Little River. Local relief throughout most of the watershed is generally less than 30 meters (100 ft).

11.2.2 REGIONAL GROUND-WATER HYDROLOGY: Strata of regional hydrologic concern that occur in the study area are those of Upper Cretaceous, Tertiary, and Quaternary ages (Table 11-1). Older sediments generally occur at depths below those that are of

TABLE II-1

GENERALIZED STRATIGRAPHY AND WATER TRANSMITTING CHARACTERISTICS OF

GEOLOGIC UNITS IN NORTHERN LOUISIANA

SYSTEM	SERIES	GEOLOGIC UNIT		DOMINANT LITHOLOGY	WATER TRANSMITTING CHARACTERISTICS
QUATERNARY	Recent	Alluvium		Gravels, sands, silts and clays.	Yields small to large quantities of water to wells regionally. Uses vary from domestic supply to irrigation supply. Hydraulic conductivity ranges from 100 feet/day to 300 feet/day (Hosman, 1978).
	Pleistocene	Terrace Deposits		Fluvial sequences of gravel, sand, silt and clay.	
TERTIARY	Eocene	CLAIBORNE GROUP	Cockfield Formation	Massive to cross-bedded, glauconitic quartz sands with interbedded silts and clays, fossils and plant material.	These formations are capable of transmitting small quantities of water locally. The hydraulic conductivity of the Cockfield Formation ranges from less than 15 feet/day to more than 40 feet/day (Hosman, 1978). These formations are present in only a small portion of the study area. Generally the Cook Mountain is not water bearing.
			Cook Mountain Formation	Fossiliferous, glauconitic, clay ironstone interbedded with brown clay and silty sands.	
			Sparta Formation	Massive, fine-grained, cross-bedded sands interbedded with sandy clays. Contains occasional lignites and fossils.	This formation is capable of transmitting large quantities of water. It is the principal aquifer in northern Louisiana. Hydraulic conductivities of this formation in the study area as determined by LETCo from aquifer tests, ranged from 1.6 feet/day to more than 100 feet/day.
			Cane River Formation	Interbedded silt and clay basal unit and upper unit. Middle of this formation is a glauconitic fossiliferous marl.	This formation is generally considered to have poor water transmitting properties regionally.
			Carrizo Formation	Fine- to coarse-grained, massive sands with minor amounts of clays, silts and lignites.	The Carrizo Formation is capable of transmitting water regionally. One LETCo aquifer test in this formation resulted in an average hydraulic conductivity value of 7.0 feet/day.
	Eocene Paleocene	Wilcox Group		Deltaic sequence of sands, silts, clays and lignites with interbeds of marine sands and clays.	Deposits of the Wilcox Group are capable of transmitting water regionally. Hydraulic conductivities of these deposits in the study area as determined from LETCo acquifer tests, ranged from 0.11 feet/day to 7.7 feet/day.
	Paleocene	Midway Group		Micaceous, fossiliferous, lignitic carbonaceous shale grading upward into sand.	These deposits are generally considered to have poor water transmitting properties regionally.
UPPER CRETACEOUS	Gulfian	NAVARRO GROUP	Arkadelphia Formation	Predominantly chalky marl with interbedded shales and clays.	This formation is generally considered to have poor water transmitting properties regionally.
			Nacatoch Formation	Marls and chalks grading upwards into fine grained sand.	This formation has good water transmitting properties in its outcrop area in southern Arkansas. In the study area, this formation generally has poor water transmitting properties. Results of aquifer testing by LETCo in the study area gave a hydraulic conductivity range of 0.03 to 1.0 feet/day.
			Saratoga Formation	Fossiliferous chalk with thin shale beds.	This formation is generally considered to have poor water transmitting properties regionally.
		Taylor Group		Predominantly chalk, shale, and marl all interbedded.	This formation is generally considered to have poor water transmitting properties regionally.
		AUSTIN GROUP	Brownstown Formation	Fine- to medium-grained sand with shale interbeds.	The Tokio Formation has good water transmitting properties in its outcrop area in southern Arkansas. In the study area, undifferentiated deposits of the Austin Group have fair water transmitting properties. Results of aquifer testing by LETCo in the study area gave a hydraulic conductivity value of 1.4 feet/day.
			Tokio Formation	Calcareous sands and shale, with some chert gravels, basal marls and chalk.	
		Eagle Ford Group		Micaceous silty shale with thin lenses of fine-grained sandstones and limestones.	This formation is generally considered to have poor water transmitting properties regionally.
		Tuscaloosa Group		Interbedded sand and shale with some calcareous beds; and a massive basal glauconitic sandstone.	This Group is capable of transmitting small quantities of water in its outcrop area in southern Arkansas.

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interest for proposed storage facilities in salt domes. The Cretaceous sediments consist of sand, sandstone, shale, marl, chalk, and some limestone. The Tertiary sediments consist of a thick sequence of alternating marine clays and terrigenous sands of the Paleocene and Eocene Epochs. Eocene sands form the principal fresh-water-bearing aquifers in the study area. Quaternary deposits occur in stream valleys largely as terrace remnants. A detailed lithologic description of the sediments in the study area is contained in Chapter 9 of this report.

Regionally, Upper Cretaceous and Tertiary sediments generally dip and thicken to the southeast. The rate of dip is approximately 19 m/km (100 ft/mi).

Geologic deposits of Upper Cretaceous and Tertiary ages that generally have good water-transmitting properties regionally include the sand beds in the Tuscaloosa Group, Austin Group, Nacatoch Formation, Wilcox Group, Carrizo Formation, Sparta Formation, and Cockfield Formation (Table 11-1). These deposits contain fresh water in their outcrop areas and for varying distances downdip.

Beds of Upper Cretaceous and Tertiary ages that generally have poor water-transmitting properties regionally include the Eagle Ford Group, Taylor Group, Saratoga Formation, Arkadelphia Formation, Midway Group, Cane River Formation, and Cook Mountain Formation (Table 11-1). The relationship between geologic strata which have regionally good and poor water-transmitting properties in northern Louisiana is illustrated in the generalized hydrogeologic cross section in Figure 11-3.

11.2.2.1 **Hydrogeology ot the Study Area:** Water is present in all of the geologic deposits investigated in this study. Water occupies the intergranular pore spaces in these deposits.

The ground-water reservoir in the study area includes all of the geologic deposits that have been investigated regionally. The water table in the Quaternary and Tertiary deposits is the upper limit of the ground-water reservoir. The base of this reservoir has not been defined. It probably occurs in Lower Cretaceous sediments not studied in this report.

Quaternary and Tertiary deposits are exposed in the study area (see Figure 9-6). Ground-water recharge to these units occurs directly from precipitation and hydraulic connection between these units and streams.

Cretaceous deposits are exposed north of the study area in southern Arkansas and eastern Texas (Figure 11-4). Recharge to these units is derived principally from rainfall and streams in those outcrop areas. Additional recharge may occur as interaquifer leakage downdip from the outcrop.

Upper Cretaceous deposits are exposed locally around some salt domes within the study area (see Figure 9-6). These units may be recharged directly from precipitation in those areas.

Results of LETCo aquifer tests (Table 11-2) indicate that sand beds in the Sparta and Carrizo Formations and in the Wilcox Group generally have good water-transmitting properties in the study area. The median hydraulic conductivity for sand beds tested in the Sparta Formation was 22 m/day (72 ft/day). The variability was high, however, ranging between 0.5 and 30 m/day

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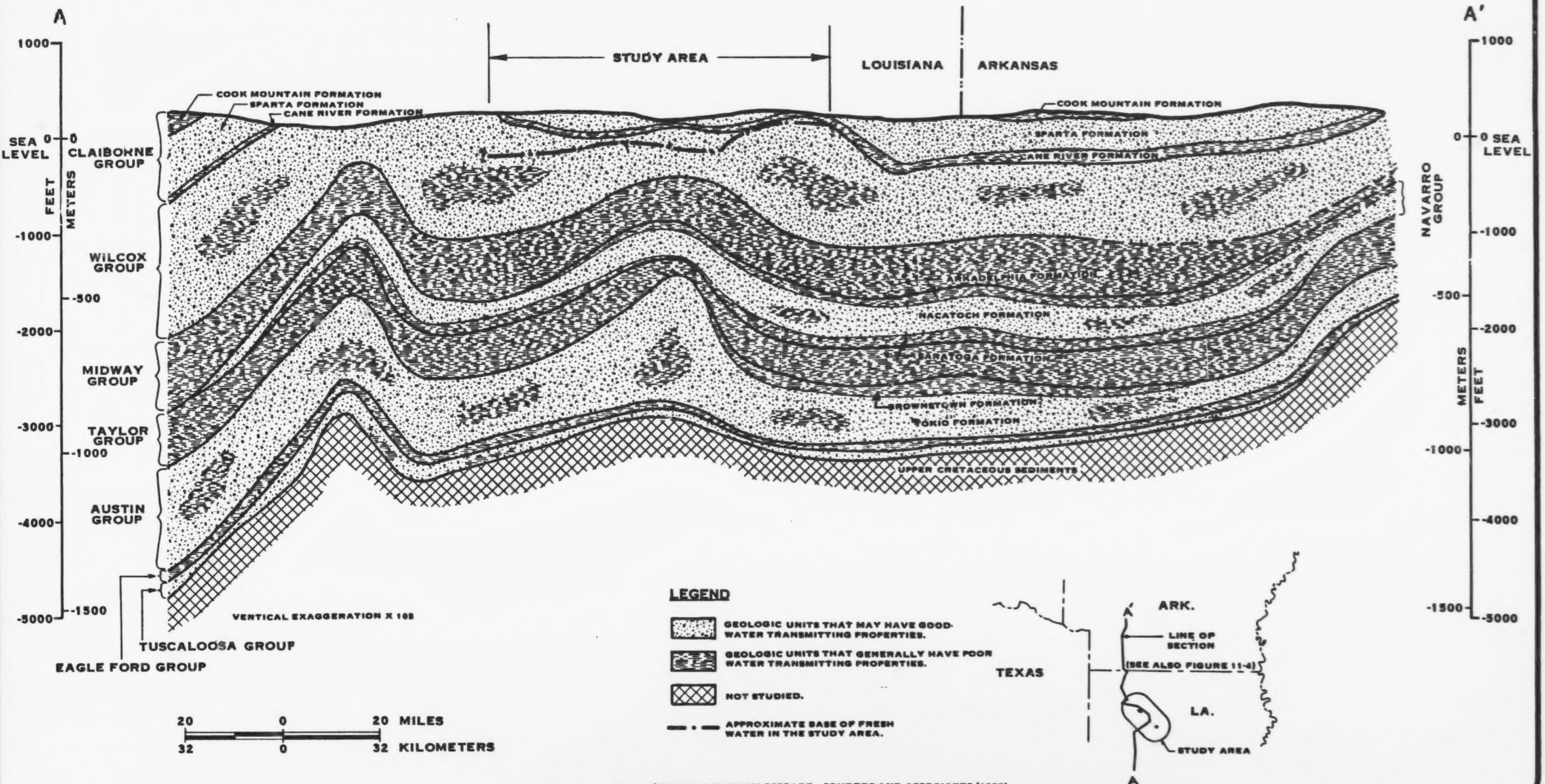

GEOLOGY MODIFIED FROM PEPPARD - SOUDERS AND ASSOCIATES (1977).

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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

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NORTH LOUISIANA STUDY AREA GENERALIZED HYDROGEOLOGIC CROSS-SECTION

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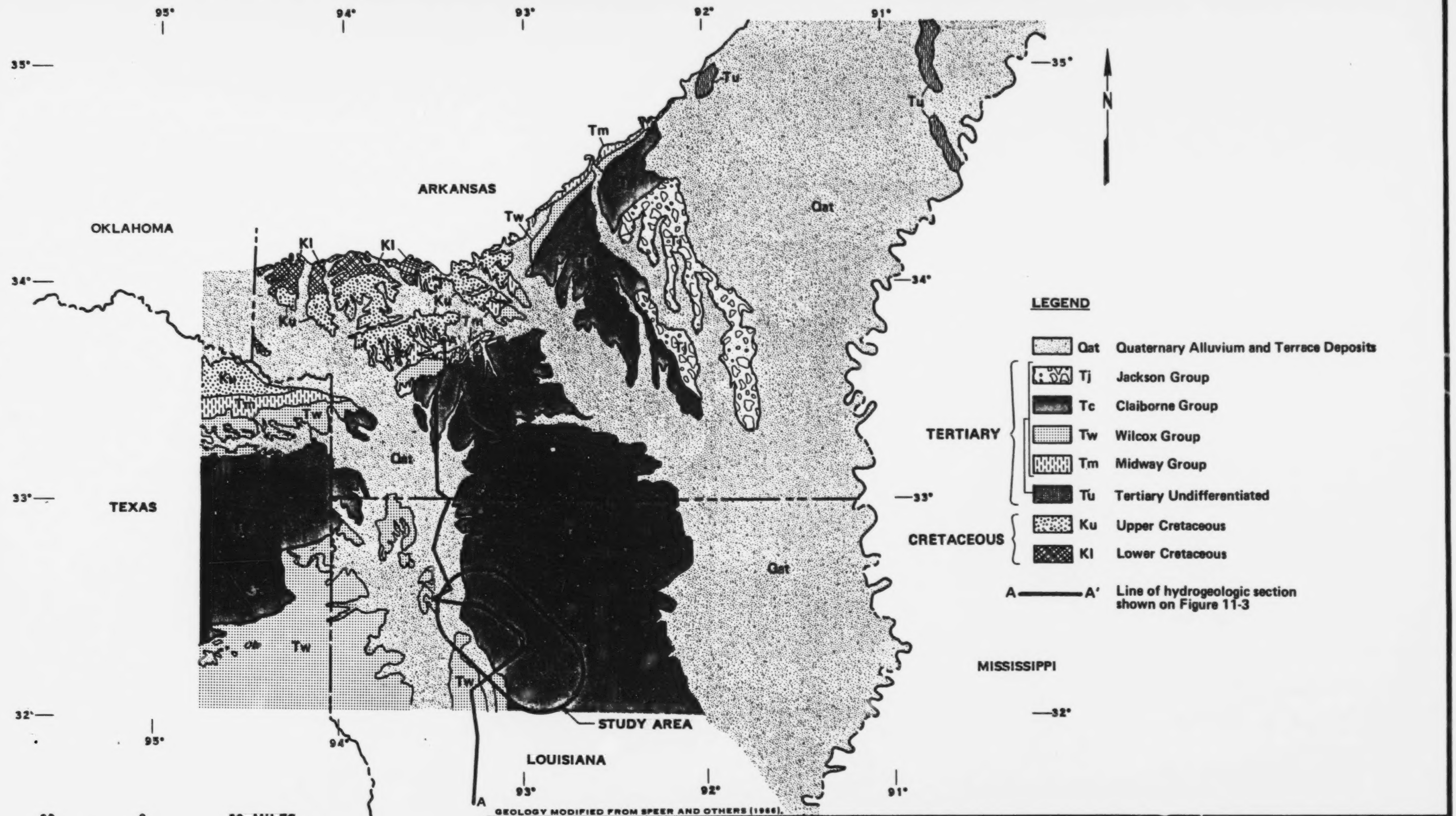
FIGURE 11-3



GEOLOGY MODIFIED FROM SPEER AND OTHERS (1966).

BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:500,000.

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NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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NORTH LOUISIANA STUDY AREA OUTCROP MAP FOR PRINCIPAL HYDROGEOLOGIC UNITS

JOB NO. MV9700 FIGURE 11-4

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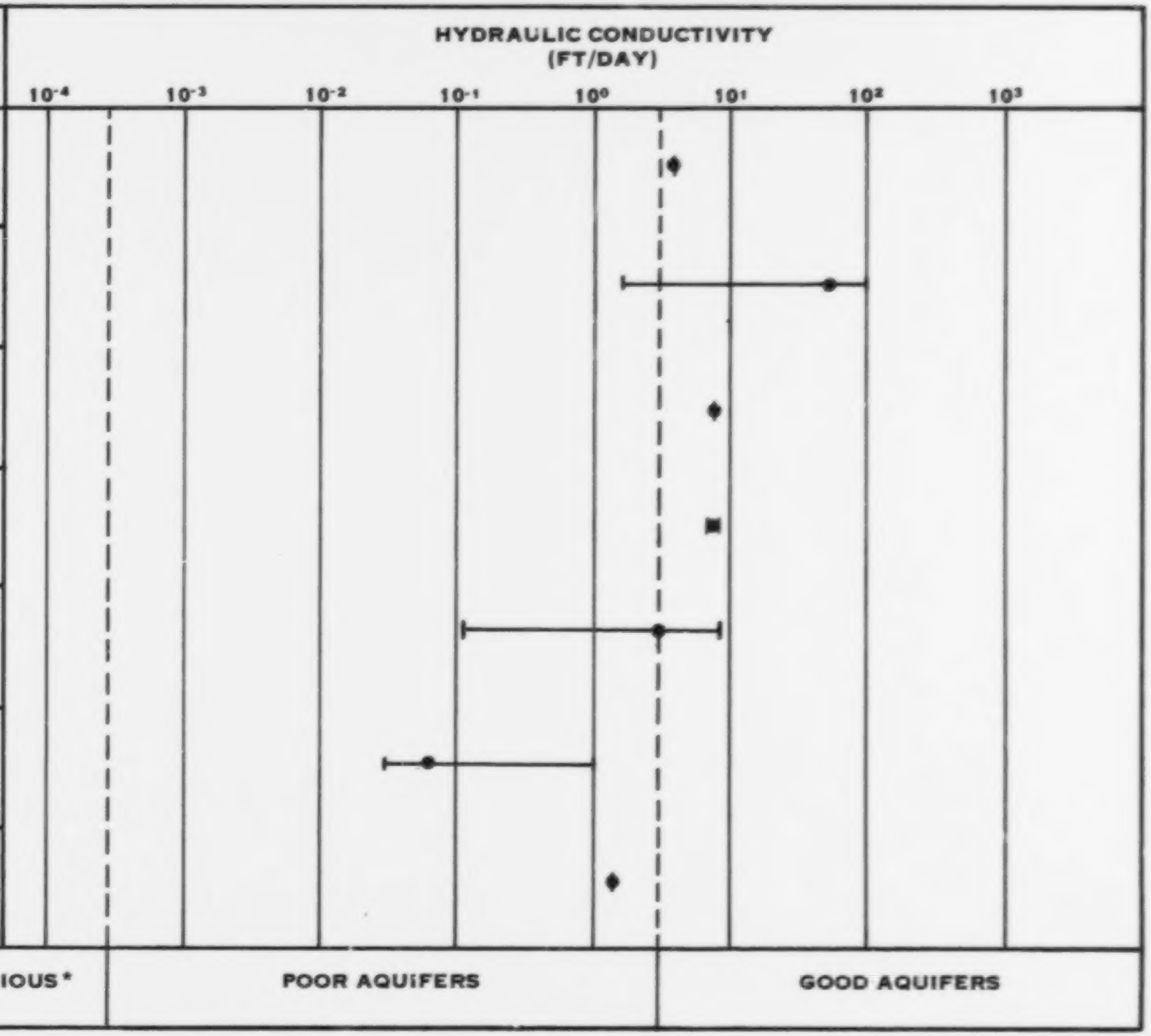
TABLE 11-2

AQUIFER TEST SUMMARY FOR SELECTED GEOLOGIC UNITS, LOUISIANA STUDY AREA

GEOLOGIC UNIT	NUMBER OF AQUIFER TEST WELLS
TERRACE DEPOSITS/ SPARTA FM.	1
SPARTA FM.	3
CARRIZO FM.	1
UPPER WILCOX GP.	1
LOWER WILCOX GP.	5
NACATOCH FM.	3
AUSTIN GP.	2



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* ADAPTED BY F.L. HOTES, FROM FAIR & GEYER,(1958)

(1.6 and 100 ft/day). A single aquifer test in the Carrizo Formation gave an average hydraulic conductivity value of 2 m/day (7 ft/day). The median hydraulic conductivity for sand beds tested in the Lower Wilcox Group was 0.8 m/day (2.8 ft/day). Again, the variability was high, ranging between 0.03 and 2 m/day (0.11 and 7.7 ft/day).

Published data for hydraulic conductivities in the Sparta and Carrizo Formations and in the Wilcox Group for Northern Louisiana are of the same order of magnitude as LETCo data. The hydraulic conductivity of sands in the Sparta Formation was reported by Hosman (1978) to range from 9 to >30 m/day (30 to >100 ft/day). Hosman (1978) indicates that the hydraulic conductivity of the Carrizo Formation is on the order of 8 m/day (25 ft/day), and that of the Wilcox Group is on the order of 5 m/day (15 ft/day).

Results of LETCo aquifer tests (Table 11-2) indicate that the sand beds in the Nacatoch Formation and the undifferentiated Austin Group are generally poor aquifers within the study area. The median hydraulic conductivity for sand beds tested in the Nacatoch Formation was 0.02 m/day (0.07 ft/day). Test results ranged from a high of 0.3 m/day (1.0 ft/day) to a low of 0.009 m/day (0.03 ft/day). The hydraulic conductivity for sand beds tested in the undifferentiated Austin Group was 0.4 m/day (1.4 ft/day).

The hydraulic conductivity of the Nacatoch Formation appears to decrease to the south and east across the study area. The hydraulic conductivity at Site LH-2 was found to average 0.2 m/day (0.8 ft/day). At Sites LVH-6 and LH-17, the average

[redacted]

hydraulic conductivity was found to be about 0.01 m/day (0.05 ft/day). An analysis of geophysical logs for the Nacatoch Formation at Site LH-7 indicated that the Nacatoch at this site was not capable of transmitting significant quantities of water.

Hydraulic conductivities for the Austin Group and the Nacatoch Formation in their outcrop areas in southwestern Arkansas are generally higher than those found in the study area. The hydraulic conductivity for sand beds in the Tokio Formation of the Austin Group in southwestern Arkansas, as reported by Counts and others (1955), averaged about 284 l/day (75 gal/day) per square foot. The hydraulic conductivity of the Nacatoch Formation in southwestern Arkansas, also reported by Counts and others (1955), is about 61 l/day (16 gal/day) per square foot. Hydraulic conductivity data were not available for the Austin Group or the Nacatoch Formation in northern Louisiana.

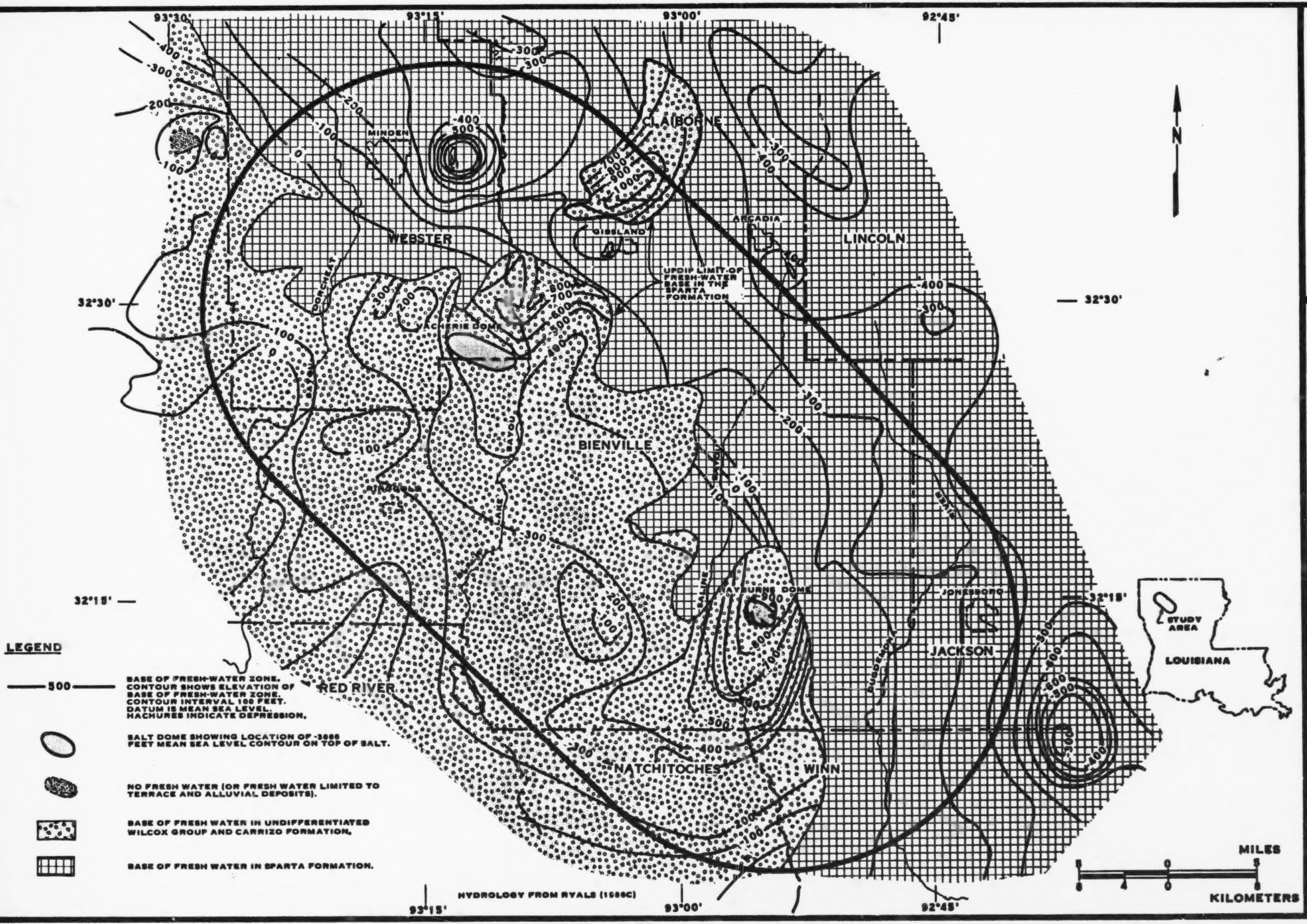
The hydrogeologic properties of the Tuscaloosa Group were not investigated in the study area because of the depth of the unit, approximately 914 meters (3,000 ft) below land surface. The hydrogeologic properties of the Cockfield Formation were not investigated because the unit occurs in only a small portion of the study area.

Multiple fresh-water bases occur in the hydrogeologic units of the study area. The basal surface of fresh water (the surface defined by all points that have water with 1,000 milligrams per liter (mg/l) [1,000 parts per million (ppm)] in total dissolved-solids) as determined by Ryals (1980c), varies from mean sea level to -305 meters (-1,000 ft) MSL within the undifferentiated

Wilcox Group and Carrizo Formation in the western part of the study area and from 30 meters (100 ft) MSL to -274 meters (-900 ft) MSL in the Sparta Formation within the eastern part of the study area (Figure 11-5). The fresh-water base in the Sparta Formation overlies the fresh-water base in the Wilcox-Carrizo deposits in part of the study area. These surfaces generally dip to the east more or less parallel to the general dip of the sediments. The clays in the Midway Group retard downward circulation of fresh water in the western part of the study area. The clays and marls in the Cane River Formation retard the downward circulation of fresh water in the eastern part of the study area.

Numerous irregularities occur in the basal fresh-water surfaces. Depression irregularities occur in these surfaces in the vicinity of many salt domes that either penetrate or nearly penetrate the land surface. Rollo (1960) suggests that these depression features are caused by the flushing of older geologic units by fresh water where these units have been exposed around domes. The depression in the fresh-water base of the Sparta Formation just east of Minden corresponds to the location of Minden Dome (Figure 11-5). Similarly, the depression in the fresh-water base of the Wilcox-Carrizo deposits in southeastern Bienville Parish coincides with the location of Rayburn's Dome.

The portion of the ground-water reservoir where saline ground water occurs can be subdivided into various saline water zones (Winslow and others, 1968). A slightly saline water zone is defined as that zone where the total dissolved-solids content of the ground water varies between 1,000 and 3,000 mg/l (1,000 and


93°30'
93°15'
93°00'
92°45'
32°30'
32°15'
WEBSTER
CLAIBORNE
LINCOLN
BIENVILLE
RED RIVER
NATCHITOCHES
WINN
JACKSON
MINDEN
GIBSLAND
ARCADIA
JONESBORO
VACHERIE DOME
RAYBURNS DOME
UPDIP LIMIT OF FRESH-WATER BASE IN THE SPARTA FORMATION
BAYOU
SALINE
DUGDEMONA
N
STUDY AREA
LOUISIANA
MILES
KILOMETERS
5
0
5
8
4
0
8
-400
-300
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
LEGEND
500
BASE OF FRESH-WATER ZONE. CONTOUR SHOWS ELEVATION OF BASE OF FRESH-WATER ZONE. CONTOUR INTERVAL 100 FEET. DATUM IS MEAN SEA LEVEL. HACHURES INDICATE DEPRESSION.
SALT DOME SHOWING LOCATION OF -3000 FEET MEAN SEA LEVEL CONTOUR ON TOP OF SALT.
NO FRESH WATER (OR FRESH WATER LIMITED TO TERRACE AND ALLUVIAL DEPOSITS).
BASE OF FRESH WATER IN UNDIFFERENTIATED WILCOX GROUP AND CARRIZO FORMATION.
BASE OF FRESH WATER IN SPARTA FORMATION.
HYDROLOGY FROM RYALS (1980C)

NORTH LOUISIANA STUDY AREA

MAP SHOWING BASE OF FRESH-WATER ZONES,PRINCIPAL HYDROGEOLOGIC UNITS

JOB NO. MV9700

FIGURE 11-5

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED RSM DATE 7/2/80
REVISED RSM DATE 12/26/80
REVISED DHP DATE 11/30/81
APPROVED GHF DATE 12/30/80

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FIGURE 11-5

3,000 ppm). A moderately saline water zone is defined as that zone where the total dissolved-solids content of the water varies between 3,000 and 10,000 mg/l (3,000 and 10,000 ppm). These zones are generally of interest to water planners. Slightly saline and moderately saline waters have potential uses and are therefore of economic value.

The basal surface of the slightly saline water zone (the surface defined by all points that have water with a total dissolved-solids content of 3,000 mg/l (3,000 ppm)), as determined by Winslow and others (1968), varies between elevations of -30 and -335 meters (-100 and -1,100 ft) MSL in the study area (Figure 11-6). This surface dips generally eastward. The surface is distorted by a depression coincident with Rayburn's Dome.

The basal surface of the moderately-saline water zone (the surface defined by all points that have water with a total dissolved-solids content of 10,000 mg/l (10,000 ppm)), as determined by Winslow and others (1968), varies between elevations of -61 and -457 meters (-200 ft and -1,500 ft) MSL in the study area (Figure 11-7). This surface closely corresponds to the basal surface of the slightly saline water zone, dipping generally eastwardly and having marked depressions at locations coincident with Minden and Rayburn's Domes.

The total dissolved-solids content of the ground water throughout most of the study area increases gradually with depth between the base surface of fresh water and the base surface of moderately saline water. One exception to this observation exists in an area near the center of the study area where very saline water (dissolved-solids content between 10,000 and 35,000 mg/l (10,000 and 35,00 ppm)) occurs near the base of the slightly saline water zone (Figure 11-7).

11.2.2.2 Water Levels and Movement: Flow directions at shallow depths in the ground-water reservoir (generally less than about 30 meters (100 ft) were determined from the shape of the water table (Figure 11-8). Water table contours were drawn using altitudes of streams and lakes, and water levels in wells. Water-level data for wells were supplied by USGS. Ground-water flows at approximately right angles to these contours from areas of higher head to areas of lower head.

The water table is a subdued replica of the topography. In general, the local topographic high areas are local ground-water recharge areas, a recharge area being defined as an area where the vertical component of ground-water flow is downward. The Bayou Dorcheat, Black Lake Bayou, Saline Bayou, and Dugdemona River Valleys are local ground-water discharge areas, or areas where the vertical component of ground-water flow is upward.

Flow directions at greater depths in the ground-water reservoir were determined from the shape of potentiometric surface maps prepared by Ryals (1980a, 1980b). The potentiometric surfaces in Figures 11-9 and 11-10 show the altitude to which water would rise in wells completed in the Sparta Formation. The potentiometric surface in Figure 11-11 shows the altitude to

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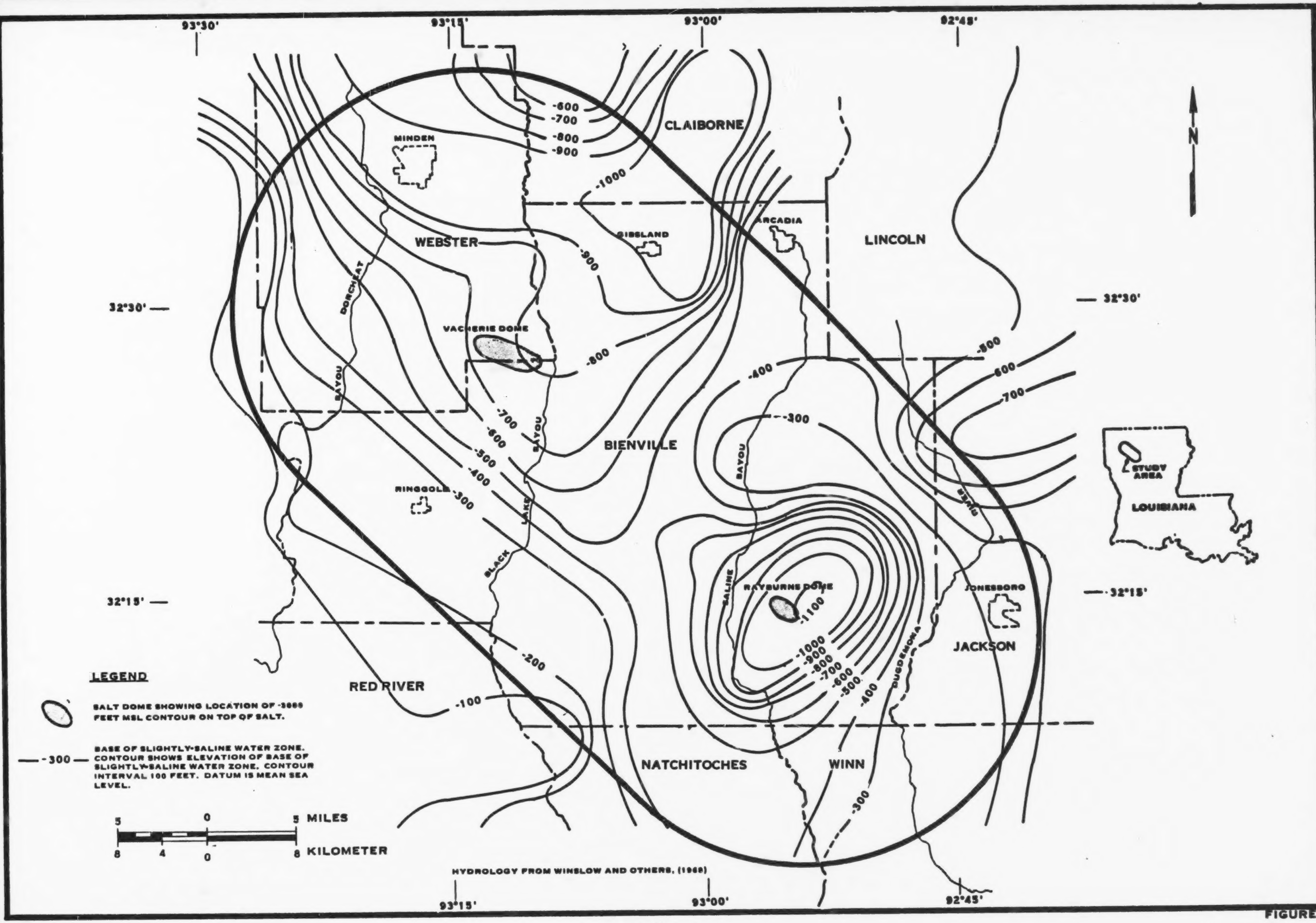

NORTH LOUISIANA STUDY AREA
BASE OF SLIGHTLY-SALINE WATER MAP

FIGURE 11-6

JOB NO. MV970C

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 11-6

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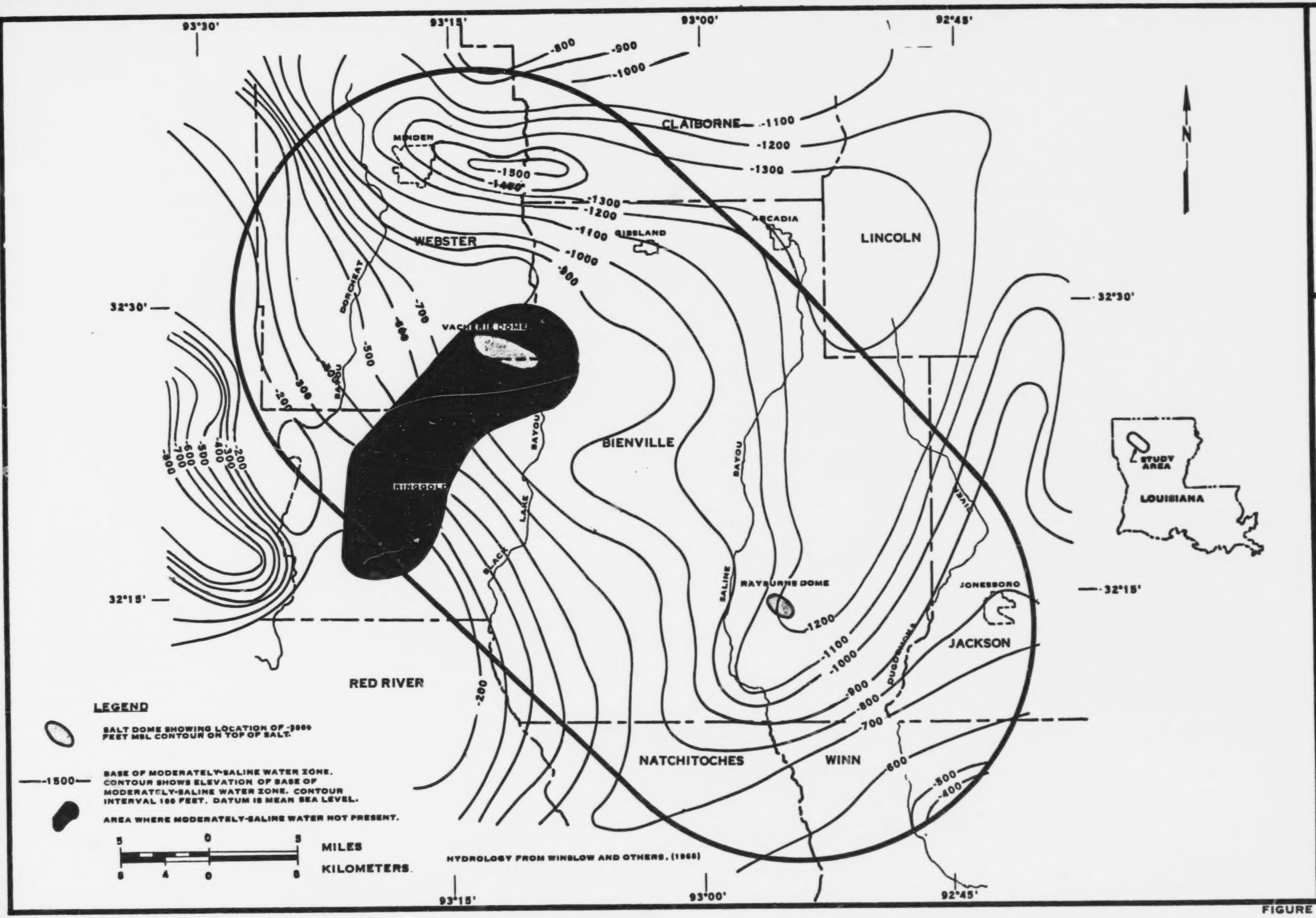

NORTH LOUISIANA STUDY AREA
BASE OF MODERATELY-SALINE WATER
MAP

JOB NO. MV9700 FIGURE 11-7

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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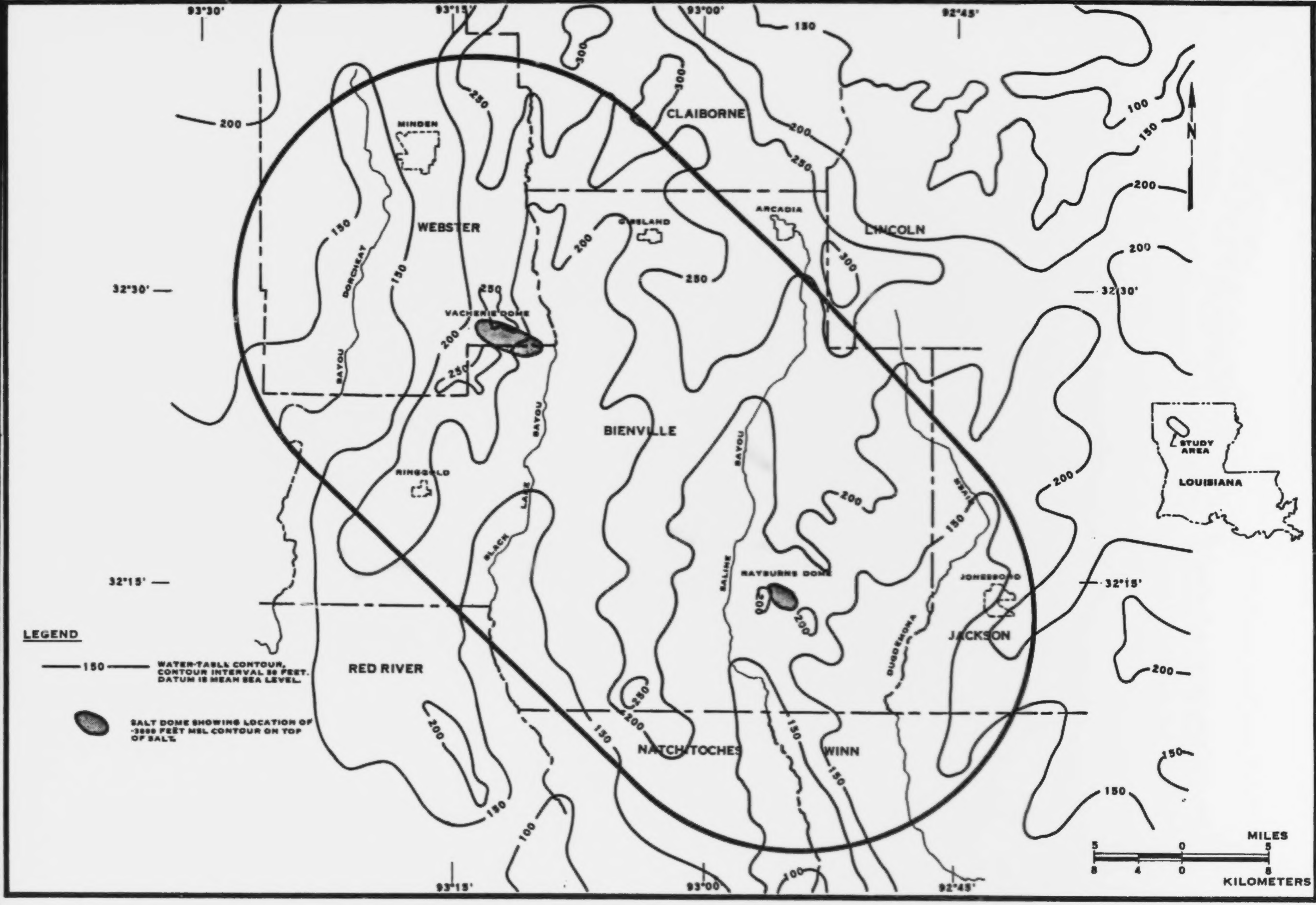
FIGURE 11-7



NORTH LOUISIANA STUDY AREA
GENERALIZED WATER-TABLE MAP

FIGURE 11-8

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NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 11-8

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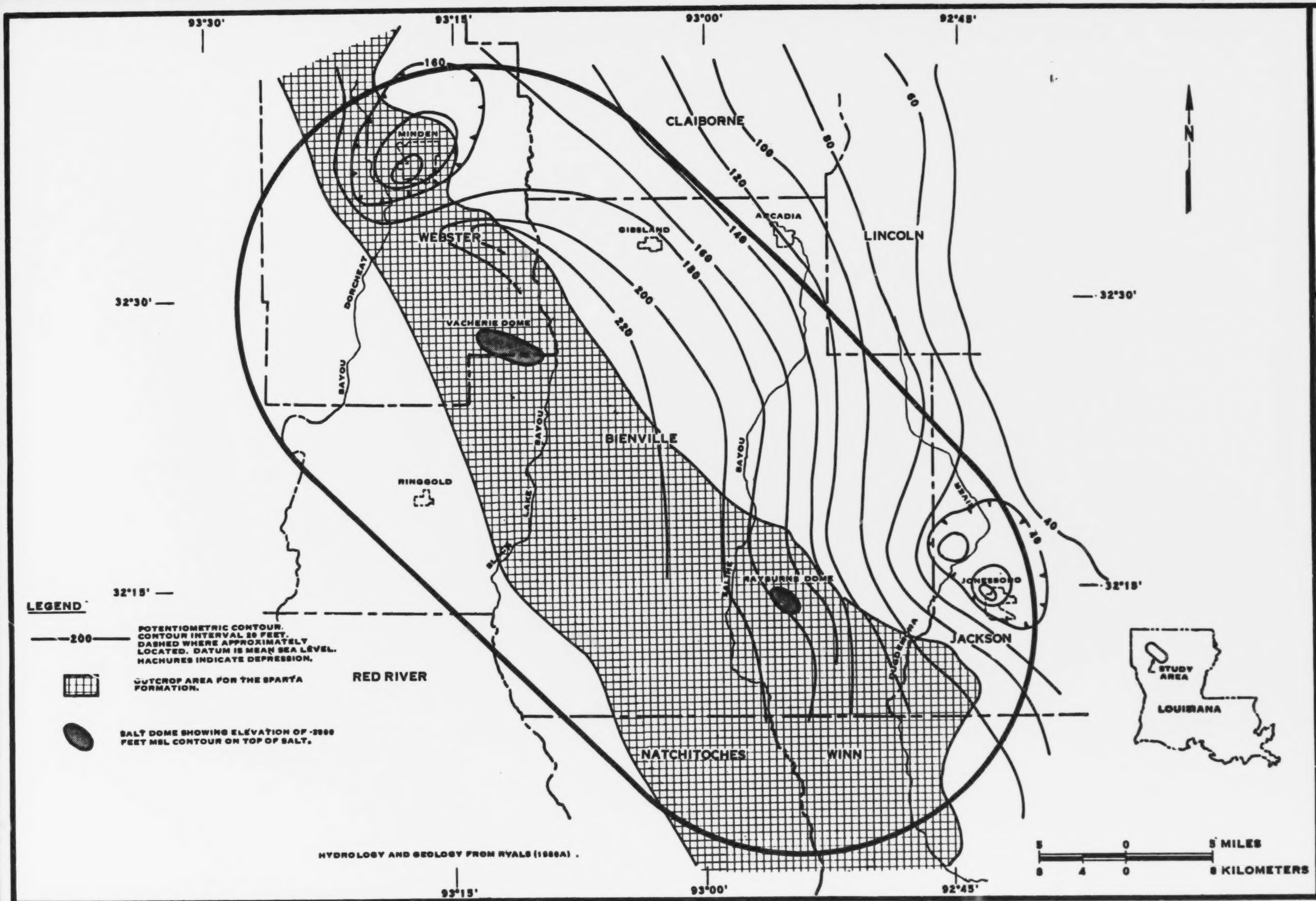

NORTH LOUISIANA STUDY AREA

MAP SHOWING POTENTIOMETRIC SURFACE OF SPARTA FORMATION

(SPRING 1980)

JOB NO. MV9700

FIGURE 11-9

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

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FIGURE 11-9

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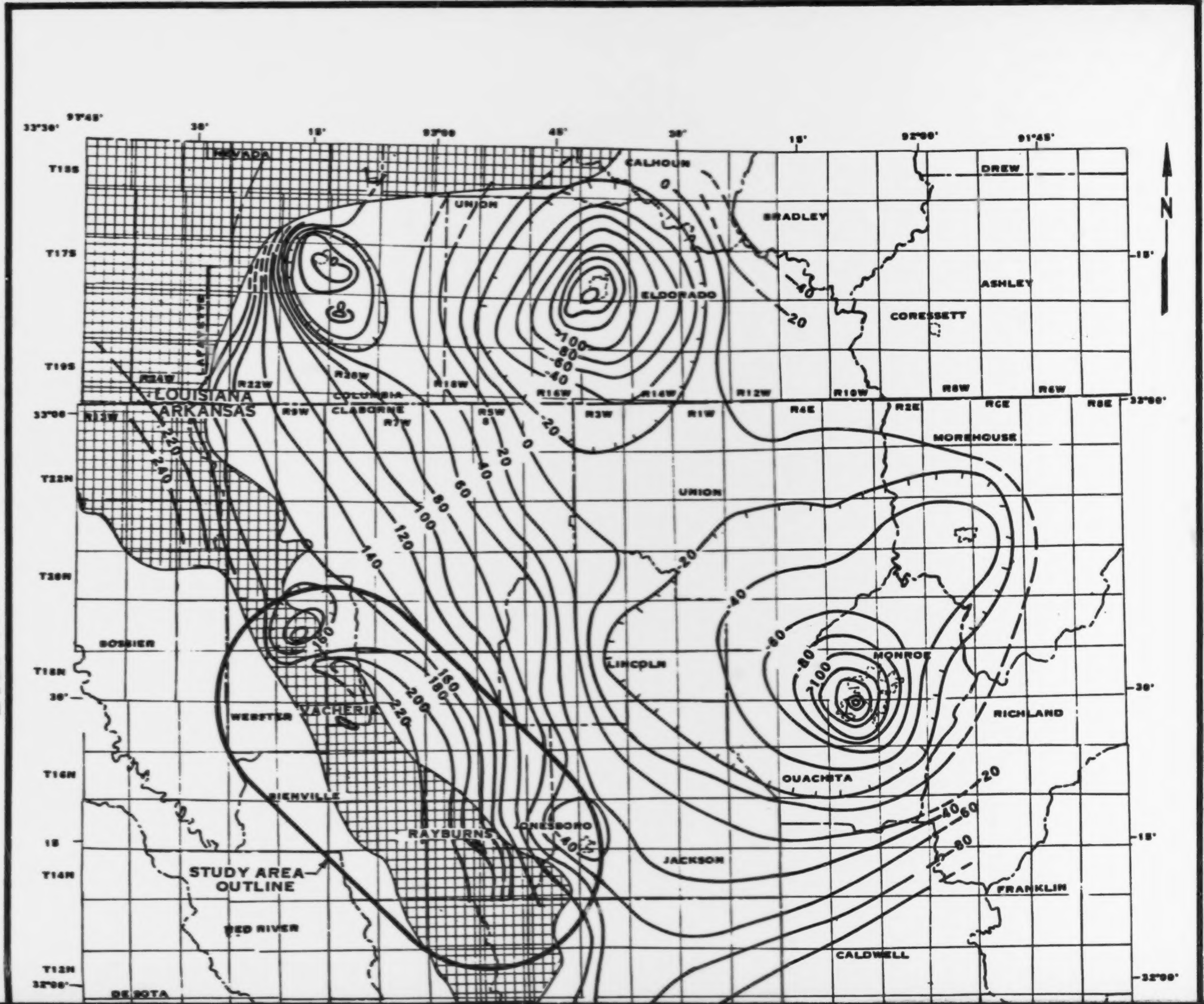
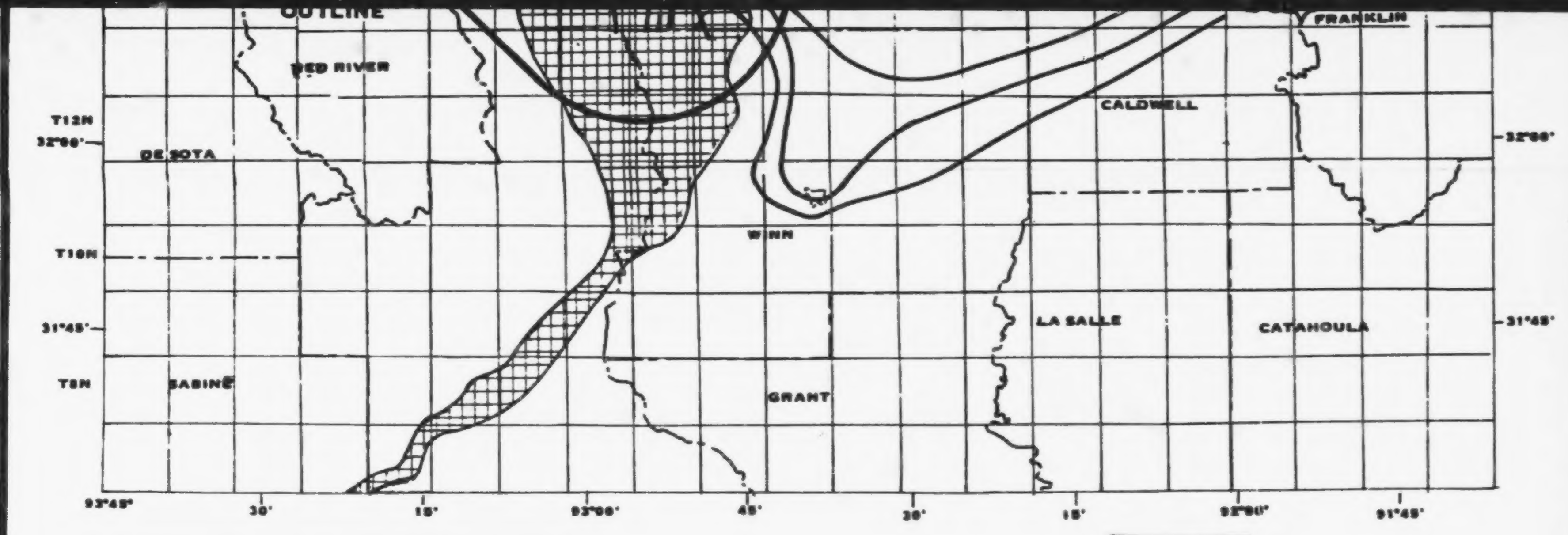




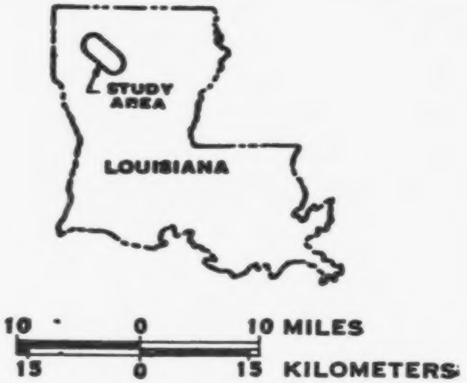
HYDROLOGY AND GEOLOGY FROM RYALS (1980) (1).

LEGEND

— 30 — POTENTIOMETRIC CONTOUR, CONTOUR INTERVAL 20 FEET, DASHED WHERE APPROXIMATELY LOCATED, HACHURES INDICATE DEPRESSION, DATUM IS MEAN SEA LEVEL.

▦ OUTCROP AREA OF THE SPARTA FORMATION.

● SALT DOME SHOWING ELEVATION OF -3000 FEET, MSL CONTOUR ON TOP OF SALT.



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NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES
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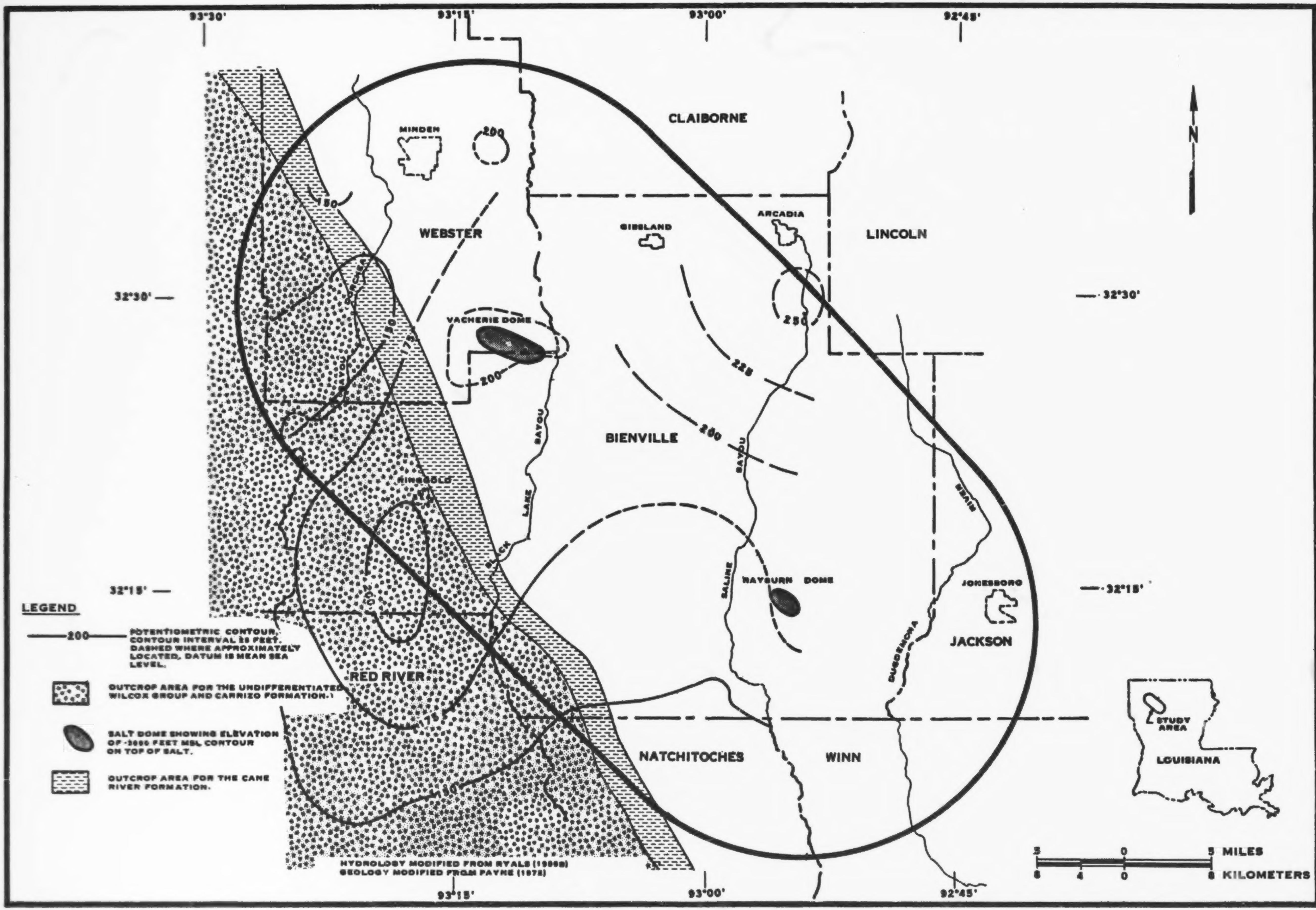
NORTH LOUISIANA STUDY AREA

MAP SHOWING REGIONAL POTENTIOMETRIC SURFACE OF SPARTA FORMATION NORTHERN LOUISIANA AND SOUTHERN ARKASAS (SPRING 1980)

JOB NO. MV9760

FIGURE 11-10

FIGURE 11-10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N
CLAIBORNE
MINDEN
WEBSTER
GIBSLAND
ARCADIA
LINCOLN
VACHERIE DOME
BIENVILLE
RINGGOLD
LAKE
BAYOU
BLACK
SALINE
DUGDEMONA
RIVER
RAYBURN DOME
JONESBORO
JACKSON
RED RIVER
NATCHITOCHES
WINN
STUDY AREA
LOUISIANA
200
175
150
225
250
75
50
5 0 5 MILES
8 4 0 8 KILOMETERS
LEGEND
200 POTENTIOMETRIC CONTOUR. CONTOUR INTERVAL 25 FEET. DASHED WHERE APPROXIMATELY LOCATED. DATUM IS MEAN SEA LEVEL.
OUTCROP AREA FOR THE UNDIFFERENTIATED WILCOX GROUP AND CARRIZO FORMATION.
SALT DOME SHOWING ELEVATION OF -3000 FEET MSL CONTOUR ON TOP OF SALT.
OUTCROP AREA FOR THE CANE RIVER FORMATION.

HYDROLOGY MODIFIED FROM RYALS (1980B)
GEOLOGY MODIFIED FROM PAYNE (1972)

NORTH LOUISIANA STUDY AREA
MAP SHOWING POTENTIOMETRIC SURFACE
OF WILCOX - CARRIZO DEPOSITS

JOB NO. MV9700 FIGURE 11-11

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 11-11

which water would rise in wells completed in the undifferentiated Wilcox-Carrizo deposits.

The general dip of the potentiometric surface in the Sparta Formation is to the east within the study area (Figure 11-9). This potentiometric surface varies from a high of approximately 67 meters (220 ft) MSL, where the Sparta Formation is recharged in its outcrop area, to a low of about mean sea level at the pumping center near Jonesboro. Water withdrawals from the Sparta Formation in the Minden and Jonesboro areas have caused local distortions in the potentiometric surface. Flow in the Sparta Formation is toward Minden and Jonesboro, where the stresses developed at these pumping centers have substantially influenced the shape of the potentiometric surface.

Water withdrawals from the Sparta Formation at Monroe, Louisiana and Eldorado, Arkansas have caused a regional distortion in the potentiometric surface (Figure 11-10). The distortion extends west from these pumping centers to near the eastern edge of the study area. Most ground water leaving the study area currently flows toward the pumping center at Monroe.

The configuration of the potentiometric surface in the undifferentiated Wilcox-Carrizo deposits is very irregular within the study area (Figure 11-11). In general, a potentiometric high extends across the center of the study area in a northeast-southwest direction. Potentiometric lows exist in both the northern and southern portions of the study area. Natural recharge to Wilcox deposits where these deposits crop out in the western part of the study area and around Vacherie Dome, together with induced pressures caused by injection well stresses in the vicinity of Arcadia, probably account for the potentiometric high area. Flow in the Wilcox-Carrizo deposits in the study area is away from the potentiometric high area and toward the potentiometric low areas.

Alterations in the potentiometric surfaces of the Sparta Formation and the undifferentiated Wilcox-Carrizo deposits which have been caused by human activities are transient changes. The potentiometric surface in the Sparta Formation, uninfluenced by human activity, would dip to the east and flow under natural conditions eastwardly to the Mississippi Valley. The Mississippi Valley is a regional discharge area for the Sparta Formation (Payne, 1968).

Generalized horizontal flow directions in the Nacatoch Formation and Austin Group were estimated from potentiometric gradients between hydrogeologic data-collection sites. The potentiometric gradient between Sites LH-2, LH-17, and LVH-6 indicates that flow in the Nacatoch Formation in the northwest part of the study area is northwesterly. The potentiometric gradient between Sites LVH-6 and LH-17 in the Austin Group indicates that flow in these deposits is southwesterly toward Site LH-17. Stresses caused by disposal wells injecting fluids into the Nacatoch Formation and Austin Group in the study area have undoubtably influenced the potentiometric surfaces in these deposits.

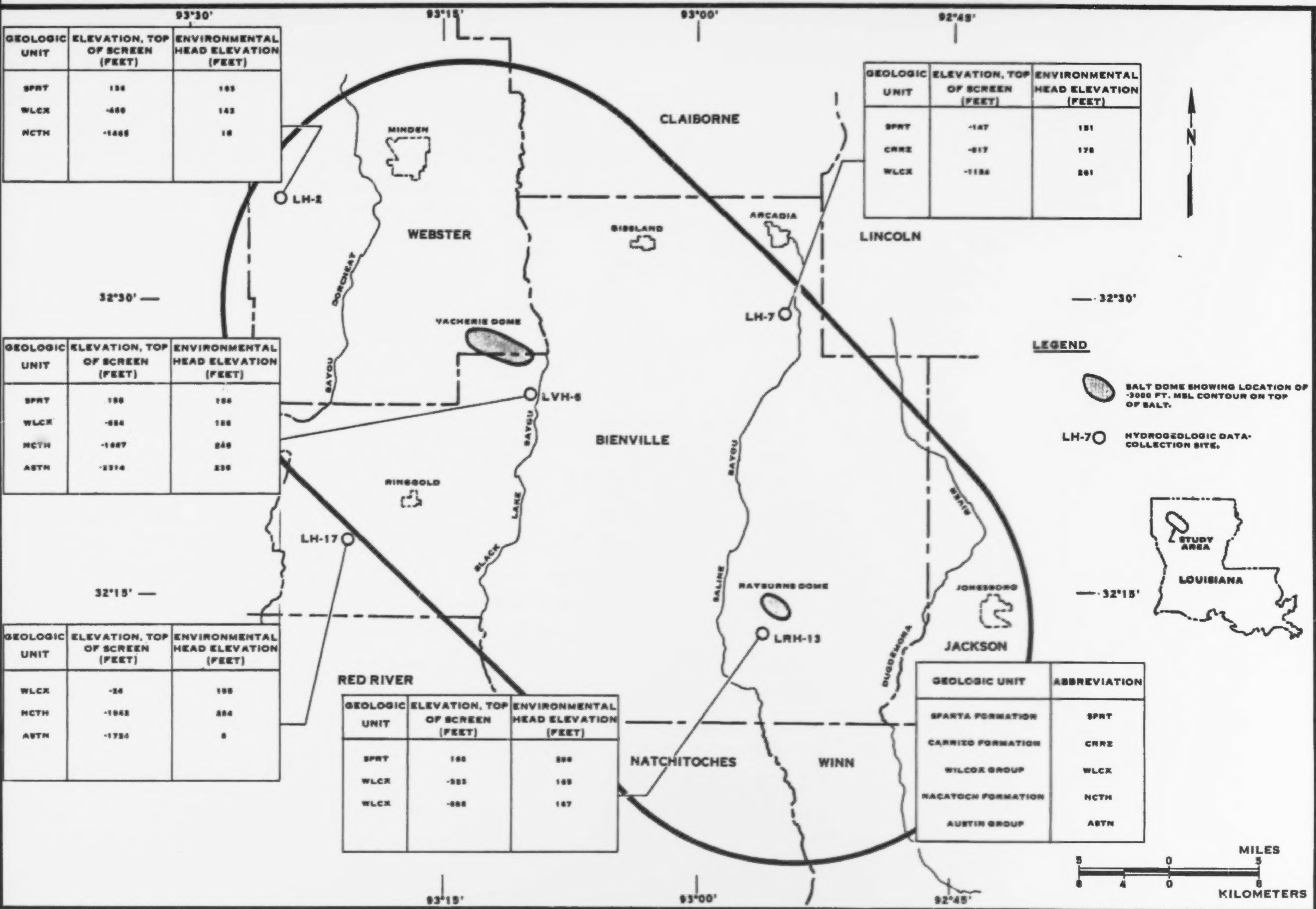
Average horizontal ground-water velocities in the Sparta Formation and the Wilcox Group were estimated on the basis of the potentiometric surface maps and effective porosity and hydraulic conductivity estimates for these deposits. The ground-water velocity in the Sparta Formation averages about 61 m/year (200 ft/yr) in the study area. The ground-water velocity in sand deposits in the lower part of the Wilcox Group, in areas where the Wilcox Group is exposed, is about 3 m/yr (10 ft/yr). The ground-water velocity elsewhere in sand deposits in the lower part of Wilcox Group areas varies between about 0.06 and 0.3 m/yr (0.2 and 1 ft). The ground-water velocity in the upper part of the Wilcox Group is about 3 m/yr (10 ft/yr) throughout the study area.

Average horizontal ground-water velocities in the Nacatoch Formation and Austin Group were estimated using potentiometric gradients between hydrogeologic data-collection sites, and effective porosity and hydraulic conductivity estimates for these deposits. The ground-water velocity in the Nacatoch Formation varies from about 0.03 m/yr (0.1 ft/yr) near Sites LVH-6 and LH-17 to about 1.2 m/yr (4 ft/yr) near Site LH-2. The ground-water velocity in the Austin Group between Sites LVH-6 and LH-17 is about 2 meters per year (8 ft/yr).

Vertical flow directions in the ground-water reservoir were determined from an analysis of the vertical distribution of environmental heads (Figure 11-12). Environmental heads show the altitude to which formation fluid, adjusted to the variable density occurring in the ground-water reservoir above the sampling point, would rise in wells (Lusczynski, 1961). There appears to be a trend toward increasing head with increasing depth through the central portion of the study area, indicating that vertical upward flow may be occurring from lower deposits. The environmental head distribution at Site LVH-6 suggests that the Austin Group and Nacatoch Formations may act as a single hydrogeologic unit in this area and that upward flow may be occurring from these deposits to the Wilcox Group. The environmental head distribution at Site LH-7 indicates that upward flow may be occurring from the lower part of the Wilcox Group to overlying deposits in this area. Conversely, environmental head distributions at Sites LH-2 and LRH-13 suggest that downward flow is occurring in the areas around these sites.

11.2.3 WATER CHEMISTRY: The chemistry of surface and ground water was investigated. Data for analyses of surface-water chemistry were sparse, while data for analyses of ground-water chemistry provided fair coverage of the study area.

The chemical character of surface waters in the study area is highly variable. Speer and others (1966) report that, during low-flow conditions, calcium, sodium, and bicarbonate are the predominant constituents in water from the Dugdemona River near Quitman (Station Number 07370820), whereas sodium and chloride are the predominant constituents in water from Saline Bayou near Lucky (Station Number 07352000) and Brushy Creek near Sibley (Station Number 07349100). (See Figure 11-13 for sampling locations.) The reported dissolved-solids content of the water from these streams was fairly uniform, however. The average dissolved-solids content for two samples was 50 mg/l (50 ppm) for the Dugdemona River, 69 mg/l (69 ppm) for the Saline Bayou, and 55 mg/l (55 ppm) for Brushy Creek (Speer and others, 1966). These streams derive part of their flow from the Sparta



LH-2

GEOLOGIC UNIT	ELEVATION, TOP OF SCREEN (FEET)	ENVIRONMENTAL HEAD ELEVATION (FEET)
SPRT	136	185
WLCX	-460	143
NCTH	-1465	18

LH-7

GEOLOGIC UNIT	ELEVATION, TOP OF SCREEN (FEET)	ENVIRONMENTAL HEAD ELEVATION (FEET)
SPRT	-147	181
CRRZ	-817	178
WLCX	-1184	261

LVH-6

GEOLOGIC UNIT	ELEVATION, TOP OF SCREEN (FEET)	ENVIRONMENTAL HEAD ELEVATION (FEET)
SPRT	198	184
WLCX	-684	186
NCTH	-1687	246
ASTN	-2314	236

LH-17

GEOLOGIC UNIT	ELEVATION, TOP OF SCREEN (FEET)	ENVIRONMENTAL HEAD ELEVATION (FEET)
WLCX	-24	198
NCTH	-1642	284
ASTN	-1724	8

LRH-13

GEOLOGIC UNIT	ELEVATION, TOP OF SCREEN (FEET)	ENVIRONMENTAL HEAD ELEVATION (FEET)
SPRT	160	299
WLCX	-323	169
WLCX	-666	167

GEOLOGIC UNIT	ABBREVIATION
SPARTA FORMATION	SPRT
CARRIZO FORMATION	CRRZ
WILCOX GROUP	WLCX
NACATOCH FORMATION	NCTH
AUSTIN GROUP	ASTN

LEGEND

▨	SALT DOME SHOWING LOCATION OF -3000 FT. MSL CONTOUR ON TOP OF SALT.
LH-7○	HYDROGEOLOGIC DATA-COLLECTION SITE.

NORTH LOUISIANA STUDY AREA
MAP SHOWING VERTICAL
HEADS AT TEST WELL SITES

JOB NO. MV9700
FIGURE 11-12

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 11-12

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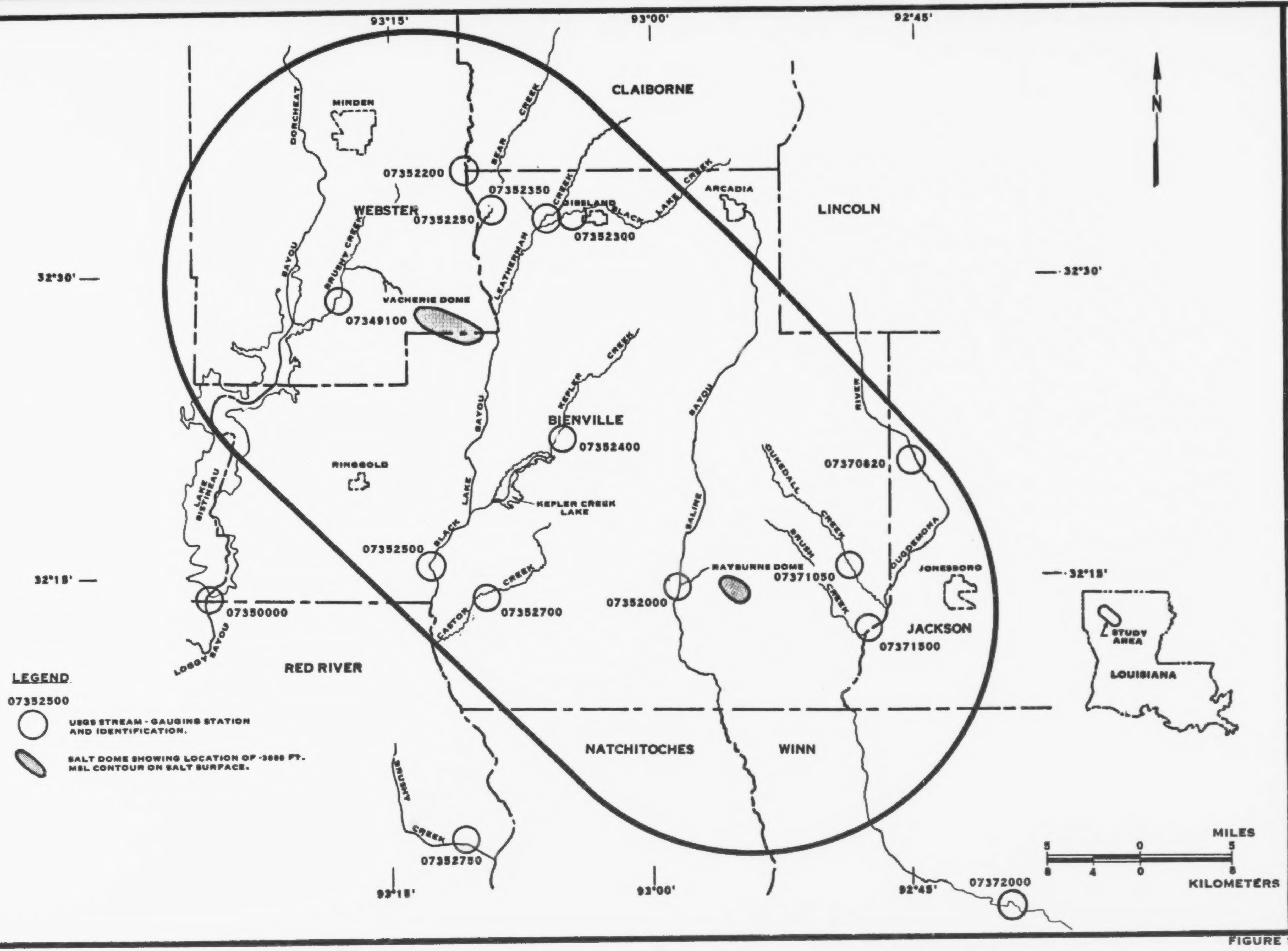

NORTH LOUISIANA STUDY AREA
STREAM LOCATIONS WHERE
LOW-FLOW CHARACTERISTICS
HAVE BEEN DETERMINED

FIGURE 11-13

JOB NO. MV9700

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 11-13

Formation. Data from the files of USGS indicate that calcium, sodium, and bicarbonate are the predominant constituents in water from Loggy Bayou near Ninock (Station Number 07350000) during low-flow conditions. The total dissolved-solids content of the water from this stream is about 165 mg/l (165 ppm). This stream derives part of its flow from alluvium and terrace deposits.

The chemical character of fresh ground water in the study area generally reflects reactions between water and aquifer materials with which the water is in contact, and the length of contact time. Table 11-3 summarizes selected chemical analyses data for ground water in and around the study area. These data consist of information on file with USGS, as well as analyses made of ground-water samples collected as part of this project.

Water from Quaternary deposits varies in chemical character according to whether the water occurs in upland terrace deposits or Red River alluvial deposits. Water occurring in upland terrace deposits is generally low in dissolved solids and relatively low in iron concentration. Water in Red River alluvium is generally high in dissolved solids and iron concentrations. Calcium and bicarbonate are generally the predominant constituents in water from both upland terrace and Red River alluvial deposits, although local variations are common. Median values for calcium, bicarbonate, and total dissolved solids are 12, 45, and 145 mg/l, (12, 45, and 145 ppm) respectively, for 19 wells from upland terrace deposits, and 110, 629, and 654 mg/l (110, 629, and 654

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TABLE 11-3

SUMMARY OF CHEMICAL ANALYSES FOR
WATER FROM SELECTED WELLS

(All values reported in milligrams per liter except pH as shown)

Geologic Unit	Statistic	pH (S.U.)	Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)	Dissolved Solids (Residue at 180°C)	Sodium Dissolved (as Na)	Chloride Dissolved (as Cl)	Bicarbonate Dissolved (as HCO_3)	Calcium Dissolved (as Ca)	Magnesium Dissolved (as Mg)	Sulfate Dissolved (as SO_4)	Iron Dissolved (as Fe)	Silica Dissolved (as SiO_2)	Potassium Dissolved (as K)
Terrace Deposits	Median	7.1	37	74	145	14	20	45	12	5.2	4.3	0.3	34	1.4
	Mean	6.8	80	114	156	18	25	93	19	7.0	5.2	0.9	35	1.6
	Range	5.2- 8.1	8- 279	8- 690	35- 274	0.2- 36	2.5- 82	10- 340	2.0- 62	0.5- 23	0.2- 21	0- 4.4	12- 53	0.4- 3.3
	No. of Samples	18	16	18	19	19	19	19	19	19	19	18	19	19
Red River Alluvium	Median	7.0	508	510	654	65	52	629	110	54	86	6.1	20	1.8
	Mean	6.9	490	560	764	76	80	598	124	57	105	7.3	19	2.0
	Range	6.2- 7.3	254- 674	200- 1300	323- 2040	17- 200	8.0- 220	[illegible]- [illegible]	29- 270	19- 140	0.7- 480	0.3- 21	14- 27	0.6- 4.8
	No. of Samples	14	17	18	17	18	18	18	17	17	18	17	17	17
Sparta Formation	Median	7.2	87	10	173	40	6.8	116	2.2	0.6	12	0.4	25	1.7
	Mean	7.1	94	17	190	54	12.7	120	4.8	1.43	19	0.9	29	2.1
	Range	4.2- 9.4	2- 271	0- 142	29- 775	1.2- 288	0- 226	2- 572	0- 40	0- 20	0- 813	0- 7.5	0- 66	0.2- 9.0
	No. of Samples	210	131	197	218	218	219	219	219	219	214	205	214	204
Carrizo-Wilcox Deposits (Undifferentiated) Fresh Water	Median	8.0	237	16.5	311	120	15	264	3.7	1.2	2.0	125	15	1.9
	Mean	7.9	320	36	376	143	41	311	14.5	5.4	3.5	630	19	2.2
	Range	5.6- 8.9	3- 593	1- 380	64- 905	7.6- 580	2.1- 540	[illegible]- 711	[illegible]- 440	0- 200	0- 2600	0- 12,000	8.2- 61	0.3- 8.4
	No. of Samples	91	70	92	91	95	93	98	92	93	93	88	92	93
Saline Water	Median	7.8	378	68	2965	1180	1420	411	16	5.5	.1	.35	12	9.5
	Mean	7.8	476	81	3292	1283	1557	514	21	6.0	51	.36	13	9.4
	Range	6.8- 8.4	167- 1060	16- 176	1185- 6790	360- 3080	19- 3690	204- 1040	3.8- 50	1.7- 14	0- 590	.03- 1.6	7.8- 18	6.9- 14
	No. of Samples	11	10	11	12	12	12	12	12	12	12	12	12	12
Nacatoch Formation	Median	7.3	151	2770	51600	18750	30800	151	661	230	<1	5.8	9.9	44
	Mean	7.5	138	2980	99590	37360	58700	138	728	234	770	7.9	10.0	147
	Range	7.0- 8.3	110- 152	1790- 4380	29330- 217830	10730- 52600	16700- 128800	110- 152	462- 1060	128- 343	<1- 2310	3.2- 14.6	6.9- 13.1	38- 360
	No. of Samples	3	3	3	3	3	3	3	3	3	3	3	3	3
Austin Group	Median	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mean	7.1	130	5070	85060	29130	48090	130	1300	320	2.6	6.5	9.8	84
	Range	6.6- 7.5	128- 132	3050- 7080	44550- 125570	15620- 42630	25850- 70330	128- 132	790- 1800	154- 484	<1- 5.2	6.8- 6.1	9.3- 10.2	57- 110
	No. of Samples	2	2	2	2		2	2	2	2	2	2	2	2

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ppm), respectively, for 18 wells from Red River alluvial deposits.

Sodium and bicarbonate are typically the predominant constituents in fresh water from the Sparta Formation. Median values for sodium and bicarbonate for 219 wells are 40 and 116 mg/l (40 and 116 ppm), respectively.

The chemical composition of fresh water in the Sparta Formation changes downdip. The dissolved solids content in the water increases from about 200 mg/l (200 ppm) in the western portion of the study area to approximately 800 mg/l (800 ppm) in the eastern portion. Increases in sodium, bicarbonate, and chloride account for most of this increase. The ratio of sodium to calcium and magnesium also increases to the east. Increases in these ratios may result from the exchange of calcium and magnesium for sodium.

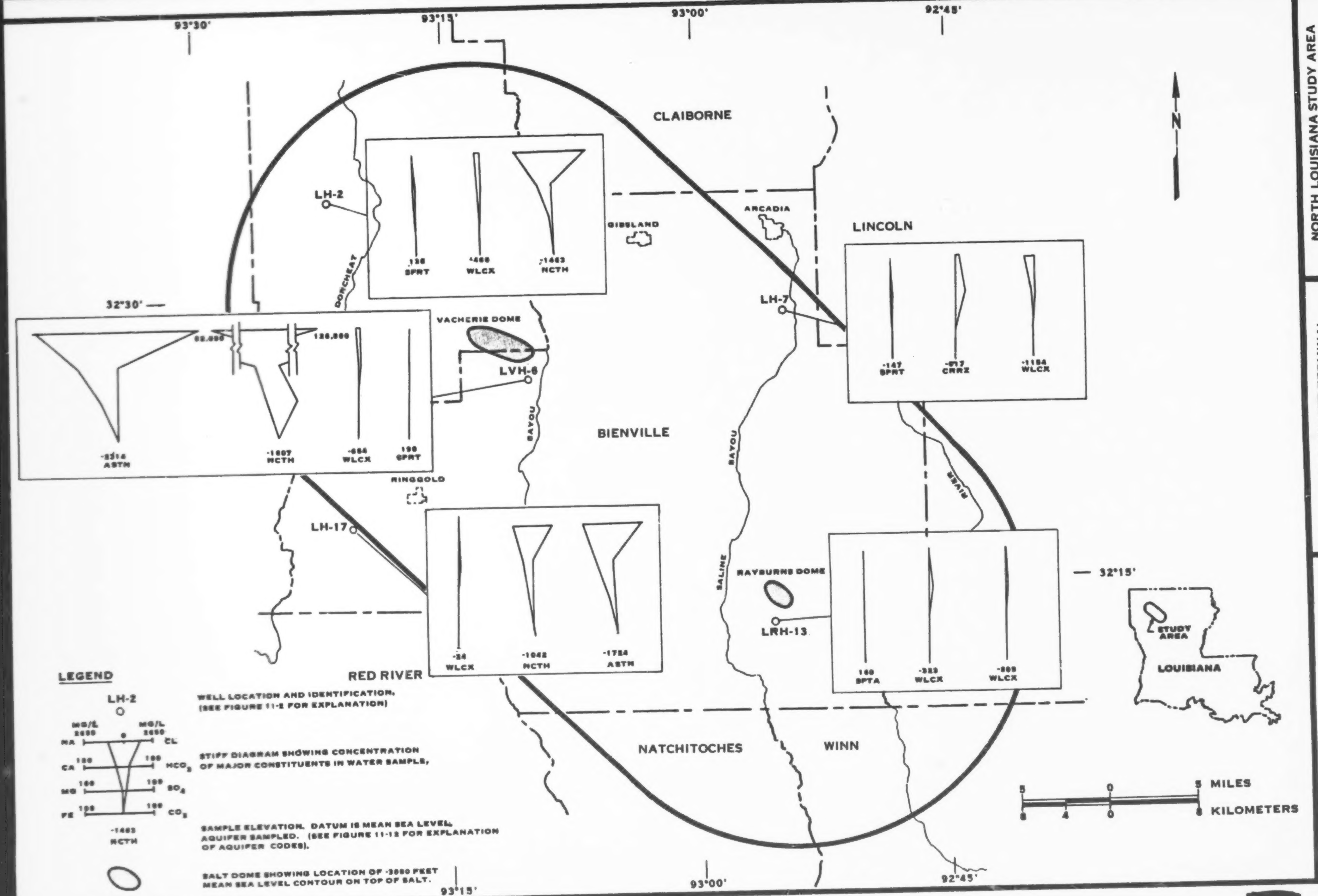
The chemical character of water from the Wilcox-Carrizo deposits varies considerably. Fresh water occurs in the outcrop area and for various distances downdip (see Figure 11-5). Sodium and bicarbonate are generally the predominant constituents in the fresh water. Median values for sodium and bicarbonate for 98 wells are 120 and 264 mg/l (120 and 264 ppm), respectively. Saline water occurs in the Wilcox-Carrizo deposits in the eastern part of the study area. Sodium and chloride are the predominant constituents in this water. Median values for sodium and chloride in the saline water are 1,180 and 1,420 mg/l (1,180 and 1,420 ppm), respectively.

The chemical character of ground water changes with increasing depth in the ground-water reservoir (Figure 11-14). The predominant constituents in the water change from calcium and bicarbonate to sodium and bicarbonate, and then to sodium and chloride. These changes probably result from increased leachate accumulation at depth caused by slower flow of water through the geologic environment coupled with less flushing of formation waters.

11.2.4 RELATIONSHIP OF SURFACE WATER TO GROUND WATER: The base flow of streams is the sustained, normal dry-weather discharge a stream can maintain. It consists largely of ground-water discharge. The base flow of streams in the study area is mainly sustained by ground water from the Quaternary deposits, Sparta Formation, and the Wilcox Group.

A quantitative measure of low flow at a point on a stream is the 7-day, 2-year low flow ($7Q_2$). This value represents the lowest mean discharge for 7 consecutive days, occurring on the average of once in 2 years at the measuring point. Values of the 7-day, 2-year low flow have been determined by Speer and others (1966) and Forbes (1980) for points along streams in the study area.

The 7-day, 2-year flow of streams in the study area generally increases to the south and east. Streams in Webster Parish and northern Bienville Parish, in the Bayou Dorcheat and Black Lake Bayou watersheds, commonly have a 7-day, 2-year low flow of less than 0.28 l/sec (0.01 ft^3/sec) per square mile of drainage area. Streams in southern Bienville Parish, in the Black Lake Bayou, Saline Bayou, and Dugdemona River watersheds, generally



NORTH LOUISIANA STUDY AREA

CHEMICAL VARIATIONS
IN GROUND WATER

FIGURE 11-14

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STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

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FIGURE 11-14

have a 7-day, 2-year low flow greater than 0.28 l/sec (0.01 ft^3/sec) per square mile of drainage area.

Variations in the low flows of streams reflect variations in the surficial geology. The 7-day, 2-year low flow streams hydraulically connected to Quaternary deposits is generally between 0.0 and 0.28 l/sec (0.01 ft^3/sec) per square mile, while the 7-day, 2-year low flow of streams hydraulically connected to the Sparta Formation is generally greater than 0.28 l/sec (0.01 ft^3/sec) per square mile. Most streams in the northeast part of the study area derive their base flow from Quaternary deposits. Many streams in the central and southwest part of the study area derive their base flow from the Sparta Formation.

11.2.5 WATER AND AQUIFER USE: Surface and ground water are used for a variety of industrial, agricultural, and municipal purposes throughout the study area. The heaviest use of water occurs around the city of Jonesboro, located in the southern part of the study area, and the city of Minden, located in the northern part of the study area. Water use in 1975 for parishes in and around the study area is summarized in Table 11-4.

Surface water is used for both industrial and rural water supply in the study area. Industrial users around Minden account for most of the surface-water withdrawals. Rural livestock supplies account for the remaining surface-water withdrawals.

Ground water is used for water supply throughout the study area. The Sparta Formation is the principal source for this supply. Municipal and industrial users account for most of the

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TABLE 11-4
SUMMARY OF 1975 WATER USE[1]
(In Million Gallons Per Day)

PARISH	PUBLIC SUPPLY		INDUSTRIAL		RURAL			IRRIGATION				TOTAL USE		
					DOMESTIC	LIVESTOCK		RICE		OTHER				
	GROUND	SURFACE	GROUND	SURFACE	GROUND	GROUND	SURFACE	GROUND	SURFACE	GROUND	SURFACE	GROUND	SURFACE	TOTAL
Bienville	.64		.69	.02	.22	.04	.07			.08		1.67	.09	1.76
Webster	4.01		8.53	17.6		.06	.03					12.60	17.63	30.23
Bossier	.99	6.00	1.48	.06	.42	.01	.06					2.90	6.12	9.02
Claiborne	1.22		1.26		.18	.07	.13					2.73	.13	2.86
Jackson	1.08		13.6		.08	.06	.12			.32		15.14	.12	15.26
Lincoln	3.50		1.67		.38	.13	.14			.11	.04	5.79	.18	5.97
Natchitoches	.42	2.70		6.58	.33	.11	.63	.31	.62		.40	1.17	10.93	12.10
Red River	.43		.47		.13	.04	.34	3.12		2.85		7.04	.34	7.38
Winn	1.41		1.13		.09	.03	.25			.27		2.93	.25	3.18
Total by Source	13.70	8.70	28.83	24.26	1.83	0.55	1.77	3.43	.62	3.63	.44	51.97	35.79	87.76
Total by Category	22.40		53.09		1.83	2.32		4.05		4.07				

[1] From Cardwell and Walter (1979)

ground-water withdrawals, with the heaviest demands centered around Minden and Jonesboro. Rural domestic and livestock supplies account for the remaining ground-water withdrawals. The location of selected high-capacity public water-supply wells is shown on Figure 11-15. Table 11-5 summarizes well construction characteristics and average withdrawal rates for these wells.

Geologic formations are utilized for the injection of industrial wastes and brines in Louisiana. There were 1,510 operating brine disposal wells in the state in 1976 and 57 active industrial waste disposal wells in the state in 1978 (Sutton, 1978). The disposal of industrial wastes is limited to geologic formations in which fresh ground waters will not be degraded, and which locally have no known hydrocarbon-bearing deposits. The disposal of brines is limited to the saline water zone of the ground-water reservoir.

Thirty-nine brine disposal wells and two chemical waste disposal wells are located in and around the study area. Disposal from these wells is generally into the Nacatoch and Tokio Formations. The closest disposal wells to Vacherie Dome are located approximately 5 km (3 mi) to the north and northeast of the dome. The closest disposal wells to Rayburn's Dome are located approximately 10 km (6 mi) to the east and southeast of that dome. Figure 11-15 shows the location of disposal wells in and around the study area and Table 11-6 summarizes their construction characteristics and injection rates.

Two facilities in the study area utilize the geologic environment for the storage of natural gas. One facility utilizes the Arcadia Dome, which is located approximately 24 km (15 mi) northeast of Vacherie Dome. This facility is capable of storing over 17 million m^3 (600 million ft^3) of natural gas. Figure 11-15 shows the location of the storage wells at Arcadia Dome. The second facility is located approximately 16 km (10 mi) north of Rayburn's Dome. This facility is currently under construction. When completed, the facility will be capable of storing more than 1.8 billion m^3 (65 billion ft^3) of gas in Lower Cretaceous sediments approximately 2,134 meters (7,000 ft) below land surface.

11.3 HYDROLOGIC CHARACTERIZATION OF CANDIDATE DOMES

The hydrology in the vicinity of Vacherie and Rayburn's Salt Domes was investigated. The knowledge gained from the regional hydrologic study, together with information contained in published reports by other investigators, and additional data gathered as part of this study, were used to define the hydrology in the vicinity of these domes.

11.3.1 VACHERIE DOME: Surface and ground-water hydrologic data were collected in the vicinity of Vacherie Dome. Ground-water hydrologic data were collected at data-collection Site LVH-6, which is located approximately 3 km (2 mi) south of the dome. Surface-water chemical and physical parameters were collected at 20 locations around the dome (see Figure 11-2).

11.3.1.1 Surface-Water Hydrology: Vacherie Dome is located almost entirely within the Bashaway Creek watershed, a minor

[redacted]

TABLE 11-5

SELECTED HIGH-CAPACITY PUBLIC WATER-SUPPLY WELLS[1]

Page 1 of 5

WELL NO.	PARISH	LOCATION	OWNER	ALTITUDE OF LAND SURFACE (FT)	DEPTH (FT)	DIAMETER (IN)	GEOLOGIC UNIT	PUMPAGE (GPM)
BI-16	Bienville	27-14N-6W	Saline	na	83	4	Wilcox Group	17
BI-128	do	do	do	na	277	2	Sparta Formation	30
BI-94	do	22-16N-6W	Bienville	na	328	6	do	56
BI-34	do	23-18N-7W	Gibsland	na	363	6	do	90
BI-35	do	do	do	na	466	6	do	150
BI-129	do	26-15N-8W	Castor	na	420	8	Wilcox Group	100
BI-52	do	34-16N-9W	Ringgold	na	na	12	Terrace Deposit	50
BI-53	do	do	do	na	na	8	do	40

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[1] From Dial (1970)

T-1633A-0

TABLE 11-5

SELECTED HIGH-CAPACITY PUBLIC WATER-SUPPLY WELLS (Continued)

WELL NO.	PARISH	LOCATION	OWNER	ALTITUDE OF LAND SURFACE (FT)	DEPTH (FT)	DIAMETER (IN)	GEOLOGIC UNIT	PUMPAGE (GPM)
BI-54	Bienville	34-16N-9W	Ringgold	na	na	na	Terrace Deposit	50
BI-130	do	do	do	na	205	4	Wilcox Group	55
BI-131	do	do	do	na	311	3	do	na
BI-132	do	do	do	na	435	6	do	80
JA-43	Jackson	31-15N-3W	Jonesboro	na	370	12	Sparta Formation	560
JA-44	do	do	do	na	505	8	do	180
JA-90B	do	do	do	na	345	6	do	na
JA-106	do	do	do	na	329	6	do	270

TABLE 11-5

SELECTED HIGH-CAPACITY PUBLIC WATER-SUPPLY WELLS (Continued)

Page 3 of 5

WELL NO.	PARISH	LOCATION	OWNER	ALTITUDE OF LAND SURFACE (FT)	DEPTH (FT)	DIAMETER (IN)	GEOLOGIC UNIT	PUMPAGE (GPM)
JA-60	Jackson	24-15N-4W	Hodge	na	na	8	Sparta Formation	60
WB-250	Webster	14-17N-9W	Heflin	na	458	3	Wilcox Group	75
WB-247	do	21-18N-9W	Sibley	na	107	12	Sparta Formation	na
WB-218	do	do	do	na	170	6	do	160
WB-157	do	21-19N-9W	Minden	na	na	na	do	na
WB-159	do	do	do	na	na	na	do	na
WB-160	do	do	do	na	na	10	do	na
WB-161	do	do	do	na	291	12	do	na

T-1633C-0

TABLE 11-5

SELECTED HIGH-CAPACITY PUBLIC WATER-SUPPLY WELLS (Continued)

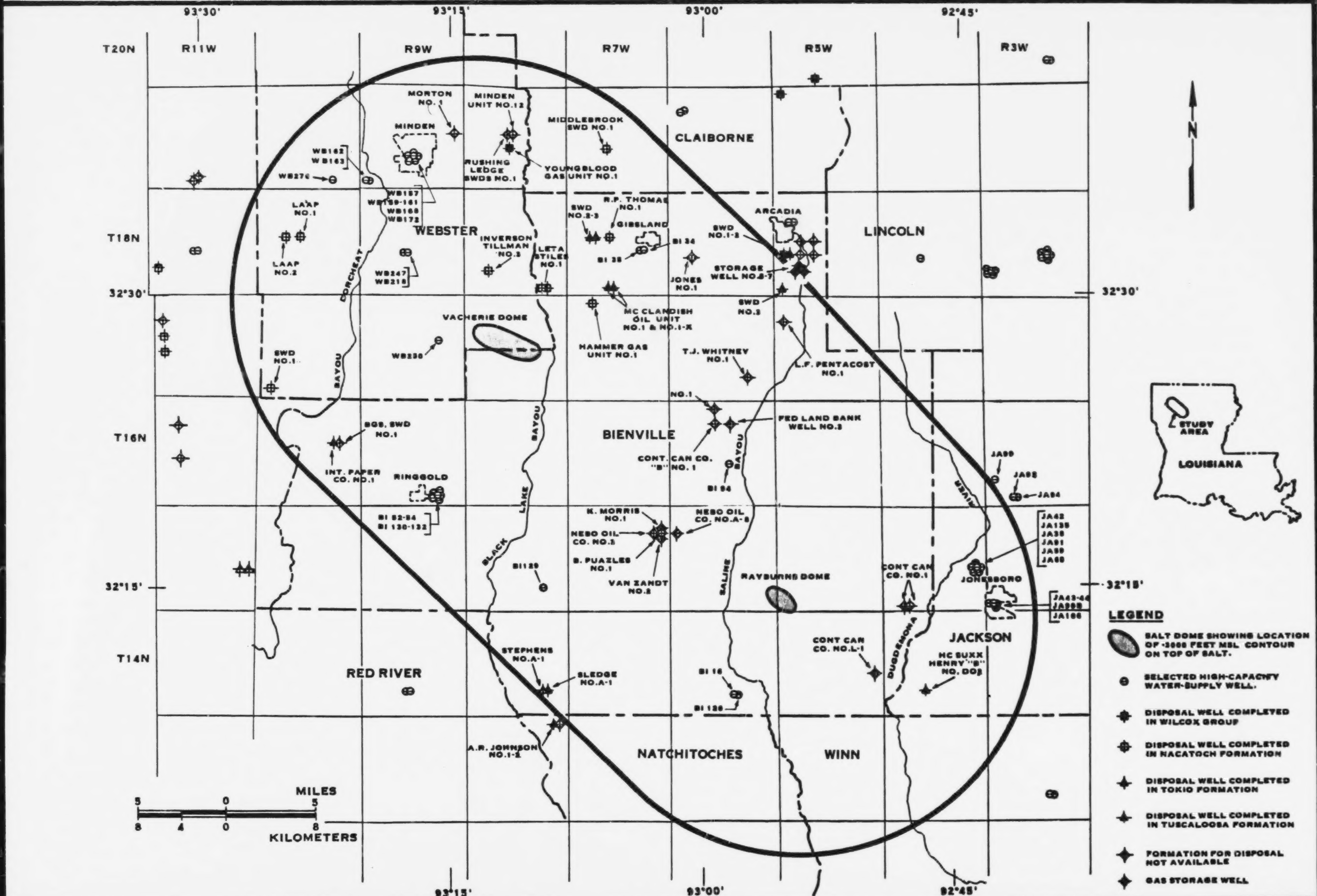
WELL NO.	PARISH	LOCATION	OWNER	ALTITUDE OF LAND SURFACE (FT)	DEPTH (FT)	DIAMETER (IN)	GEOLOGIC UNIT	PUMPAGE (GPM)
JA-99	Jackson	30-16N-3W	Qutiman	na	607	6	Sparta Formation	70
JA-92	do	32-16N-3W	Punkin Center Hilltop	na	580	4	do	90
JA-94	do	do	do	na	580	6	do	90
JA-42	do	24-15N-4W	Hodge	na	343	12	do	500
JA-135	do	do	do	na	380	8	do	750
JA-38	do	do	do	na	516	6	do	300
JA-91	do	do	do	na	510	4	do	300
JA-59	do	do	Hodge	na	na	8	do	75

TABLE 11-5

SELECTED HIGH-CAPACITY PUBLIC WATER-SUPPLY WELLS (Continued)

Page 5 of 5

WELL NO.	PARISH	LOCATION	OWNER	ALTITUDE OF LAND SURFACE (FT)	DEPTH (FT)	DIAMETER (IN)	GEOLOGIC UNIT	PUMPAGE (GPM)
WB-168	Webster	21-19N-9W	Minden	na	245	3	Sparta Formation	100
WB-172	do	do	do	na	na	8	Terrace Deposit	25
WB-162	do	31-19N-9W	Dixie Inn	na	204	8	Sparta Formation	na
WB-163	do	do	do	na	204	8	do	na
WB-276	do	35-19N-10W	McIntyre Waterworks District	na	190	6	Wilcox Group	100



NORTH LOUISIANA STUDY AREA
LOCATION OF INJECTION WELLS
AND SELECTED HIGH-CAPACITY WATER-SUPPLY WELLS.

JOB NO. MV9700

FIGURE 11-15

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED RSM DATE 12/26/80
REVISED Ccy DATE 4/30/81
REVISED DATE
APPROVED GHF DATE 12/30/80

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FIGURE 11-15 [redacted]

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TABLE 11-6

DISPOSAL WELLS PERMITTED BEFORE 1979

Page 1 of 5

WELL NO.	PARISH	LOCATION/FIELD	OWNER	ALTITUDE OF LAND SURFACE (FT)	DISPOSAL INTERVAL (FT)	GEOLOGIC UNIT TARGET	AVERAGE INJECTION RATE (BARRELS PER DAY)
Continental Can No. 1	Bienville	32-15N-4W Danville	Franks, Grigsby and King	160	1530 to 1630	na	350
Continental Can No. 1	do	32-15N-4W Danville	Pan Am U. Hoss SUK	na	1869 to 7250	na	na
Continental Can No. L-1	do	24-14N-5W Danville	Petrofund, Inc.	146	1428 to ?	na	70
L.F. Pentacost No. 1	do	7-17N-5W Bryceland	Skelly Oil Co.	na	na	na	na
SWD No. 1	do	19-18N-5W Arcadia Dome	Tuloma Gas Products Company	na	1200 to 1370	Wilcox Group	na
SWD No. 2	do	19-18N-5W Arcadia Dome	do	na	2950 to 3250	Tokio Formation	na
SWD No. 3	do	31-18N-5W Arcadia Dome	do	na	na	Tokio Formation	20,000
Nebo Oil Co. No. 1-8	do	7-15N-6W Lucky	Placid Oil Co.	244	2563 to 2573	na	100

TABLE 11-6

DISPOSAL WELLS PERMITTED BEFORE 1979 (Continued)

Page 2 of 5

WELL NO.	PARISH	LOCATION/FIELD*	OWNER	ALTITUDE OF LAND SURFACE (FT)	DISPOSAL INTERVAL (FT)	GEOLOGIC UNIT TARGET	AVERAGE INJECTION RATE (BARRELS PER DAY)
No. 1	Bienville	4-16N-6W Bear Creek	Harvey Broyles, CVRASUB, Poole, et al	na	2238 to 4483	na	23
Continental Can Co. "B" No. 1	do	9-16N-6W Bear Creek	Brammer Engineering, Inc.	na	2228 to ?	na	50
Fed. Land Bank Well No. 3	do	10-16N-6W Bear Creek	Southern National Gas Company	285	1777 to 3041	na	200
Hess B. SUB T.J. Whitney No. 1	do	26-17N-6W Bryceland	Monsanto Comapny	257	2353 to 6600	na	10
U. Hoss SUG; Jones No. 1	do	20-18N-6W West Arcadia	Crystal Oil and Land	na	1580 to 6040	na	20
Kate Morris No. 1	Bienville	12-15N-7W Lucky	Lamar Hunt Trust	249	524 to 2099	na	47
Dee Van Zandt No. 2	do	12-15N-7W Lucky	do	217	531 to 2367	na	139
B. Quarles No. 1	do	12-15N-7W Lucky	do	216	495 to 2233	na	86

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TABLE II-6

DISPOSAL WELLS PERMITTED BEFORE 1979 (Continued)

Page 3 of 5

WELL NO.	PARISH	LOCATION/FIELD	OWNER	ALTITUDE OF LAND SURFACE (FT)	DISPOSAL INTERVAL (FT)	GEOLOGIC UNIT TARGET	AVERAGE INJECTION RATE (BARRELS PER DAY)
Nebo Oil Company No. 3	Bienville	12-15N-7W Lucky	Lamar Hunt Trust	241	510 to 2408	na	83
Hammer Gas Unit No. 1	do	5-17N-7W Ada	Atlantic Refg. Company	na	2033 to 2040	Nacatoch Formation	na
R.P. Thomas No. 1	do	16-18N-7W Gibsland Dome	Hercules Petroleum Corp.	202	882 to 900	do	na
SWD No. 2	do	17-18N-7W Gibsland Dome	do	200	2800 to 3200	Tokio Formation	15,000
SWD No. 3	do	17-18N-7W Gibsland Dome	do	200	2800 to 3200	do	15,000
McClandish Oil Unit No. 1-X	Bienville	33-18N-7W Ada	Atlantic Richfield Company	na	2815 to 2835	Tokio Formation	200
McClandish Oil Unit 1; No. 1	do	33-18N-7W Ada	do	na	2800 to 2820	do	200
Stephens No. A-1	do	26-14N-8W Topy Creek	Phillips Petroleum Company	na	3156 to 3185	Tuscaloosa Formation	na

TABLE 11-6

DISPOSAL WELLS PERMITTED BEFORE 1979 (Continued)

Page 4 of 5

WELL NO.	PARISH	LOCATION/FIELD	OWNER	ALTITUDE OF LAND SURFACE (FT)	DISPOSAL INTERVAL (FT)	GEOLOGIC UNIT TARGET	AVERAGE INJECTION RATE (BARRELS PER DAY)
Sledge No. A-1	Bienville	26-14N-8W Topy Creek	Phillips Petroleum Company	na	3156 to 3220	Tuscaloosa Formation	na
Leta Stiles No. 1	do	35-18N-8W Ada	Phillips Petroleum Company	na	1780 to 1805 1815 to 1845	Nacatoch Formation	na
Leta Stiles No. 1	do	35-18N-8W Ada	Humble Oil and Refining Company	na	1780 to 1845	do	na
BGS. SWD No. 1	do	14-16N-10W Lake Bistineau	United Gas Pipeline Company	na	2632 to 2638	Tuscaloosa Formation	1000
Int. Paper Company No. 1	do	14-16N-10W Lake Bistineau	Watson Oil Corp.	na	1790 to 1950	na	na
Middle Brook SWD No. 1	Claiborne	21-19N-7W Leatherman Creek	McGoldrick Oil Company	310	2290 to 2310	Nacatoch Formation	300
HC SUXX Henry "B" No. D02	Jackson	28-14N-4W Danville	Phillips Petroleum Company	162	3260 to 3510	Tokio Formation	200
A.R. Johnson No. 2	Natchitoches	1-13N-8W Ashland	Marlin Expl. Inc.	na	3154 to 3191	Tuscaloosa Formation	800

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TABLE 11-6

DISPOSAL WELLS PERMITTED BEFORE 1979 (Continued)

Page 5 of 5

WELL NO.	PARISH	LOCATION/FIELD	OWNER	ALTITUDE OF LAND SURFACE (FT)	DISPOSAL INTERVAL (FT)	GEOLOGIC UNIT TARGET	AVERAGE INJECTION RATE (BARRELS PER DAY)
A. R. Johnson No. 1	Natchitoches	1-13N-8W Ashland	Peterson Drlg. Co./Gulfshore Oil Company	220	1498 to 1518 1941 to 1960 2199 to 2235	na	na
Inverson-Tillman No. 3	Webster	29-18N-8W Ada	David Crow	na	1746 to 1900	Nacatoch Formation	na
Minden Unit No. 3; No. 12	do	16-19N-8W Minden	Barnwell Drilling Company	94	1785 to 1820	na	na
Rushing Lease SWDS No. 1	do	16-19N-8W Minden	do	259	1700 to 1720	na	na
Youngblood Gas Unit No. 1	do	21-19N-8W Minden	Pan Am	na	2020 to 2030	Wilcox Group	na
Morton No. 1	Webster	13-19N-9W Minden	Monsanto Company	na	1510 to 1650	na	120
SWD No. 1	do	31-17N-10W Sligo	United Gas Pipe Line Company	na	1078 to 1095	do	50
LAAP No. 1	do	16-18N-10W na	Sperry Rand Corp.	na	1580 to 1710	Nacatoch Formation	2400
LAAP No. 2	do	17-18N-10W na	do	na	na	do	2400

tributary to Black Lake Bayou (Figure 11-16). The watershed is located along the Webster-Bienville Parish line and drains an area of 18.3 km^2 (7.1 mi^2).

11.3.1.1.1 Domal Area Drainage - Bashaway Creek extends almost directly along the major axis of the dome. Bashaway Creek watershed is characterized by gently rolling hills with a relatively wide alluviated flood plain. Surface elevations range from 50 to 120 meters (165 to 395 ft) MSL. The drainage pattern of Bashaway Creek is dendritic with streambed slopes ranging from greater than 9 m/km (50 ft/mi) at the headwaters to approximately 2 m/km (12 ft/mi) near the mouth.

The northwest end of the dome is located along the drainage divide between Bashaway Creek and Parmers Creek, a small, second-order tributary to Bayou Dorcheat.

11.3.1.1.2 Historical Floods - There are no published records of floods for Bashaway Creek.

The nearest USGS stream-gauging stations are Black Lake Bayou near Minden (Station #07352200), approximately 18 km (11 mi) upstream from the confluence with Bashaway Creek, and Black Lake Bayou near Castor (Station #07352500), approximately 24 km (15 mi) downstream from the confluence with Bashaway Creek (see Figure 11-13).

Discharge records are available for the Minden station for the periods from 1951 to 1968, and from 1974 to the present. Continuous discharge records are available for the period from

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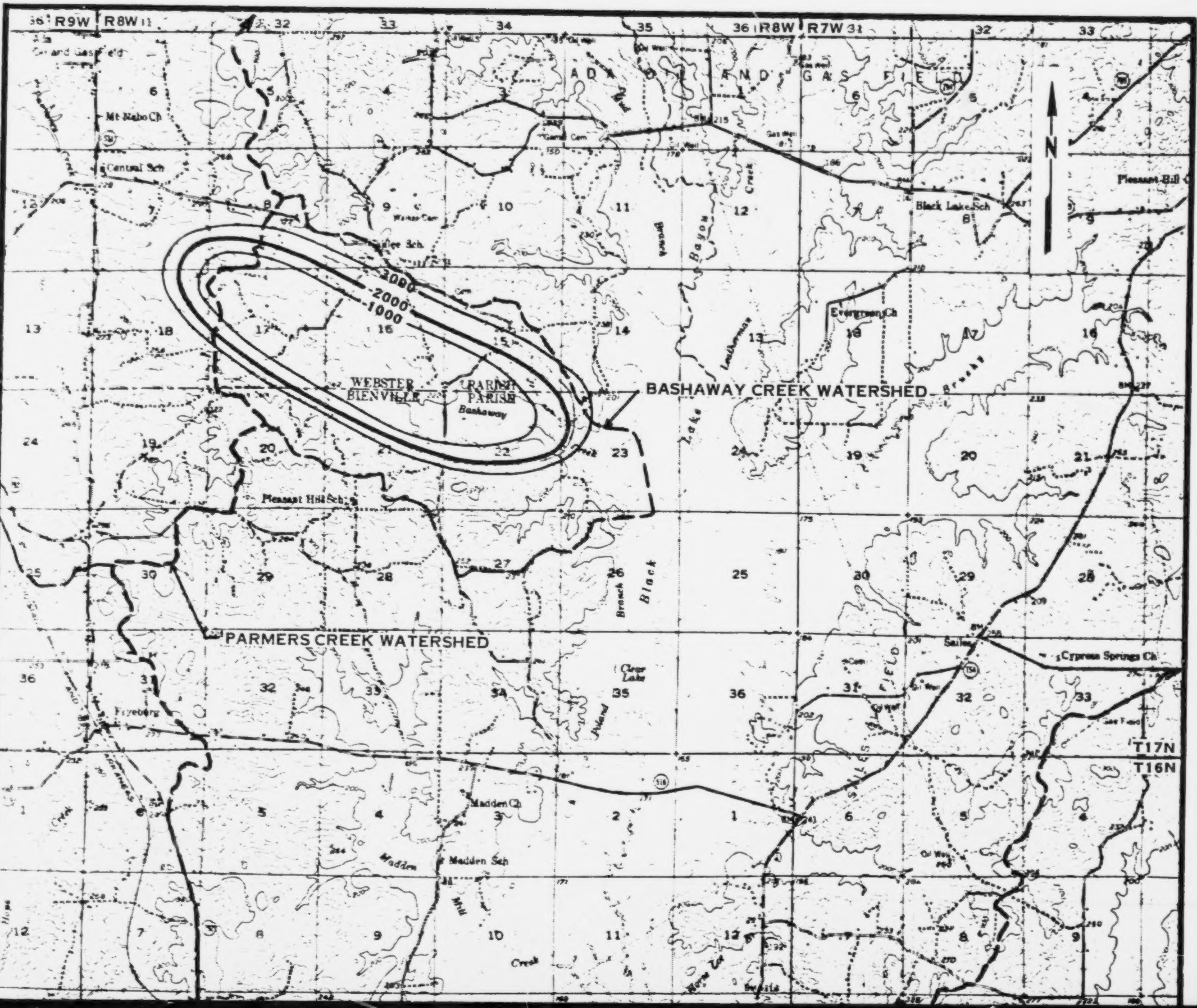
R9W
R8W
R8W
R7W
ADA OIL AND GAS FIELD
N
Mt Nebo Ch
Central Sch
Black Lake Sch
Pleasant Hill Ch
Evergreen Ch
3000
2000
1000
WEBSTER
BIENVILLE
PARISH
PARISH
Bashaway
BASHAWAY CREEK WATERSHED
Pleasant Hill Sch
PARMERS CREEK WATERSHED
Black Lake Bayou
Clear Lake
Cypress Springs Ch
Saline
Fryeburg
Madden Ch
Madden Sch
T17N
T16N

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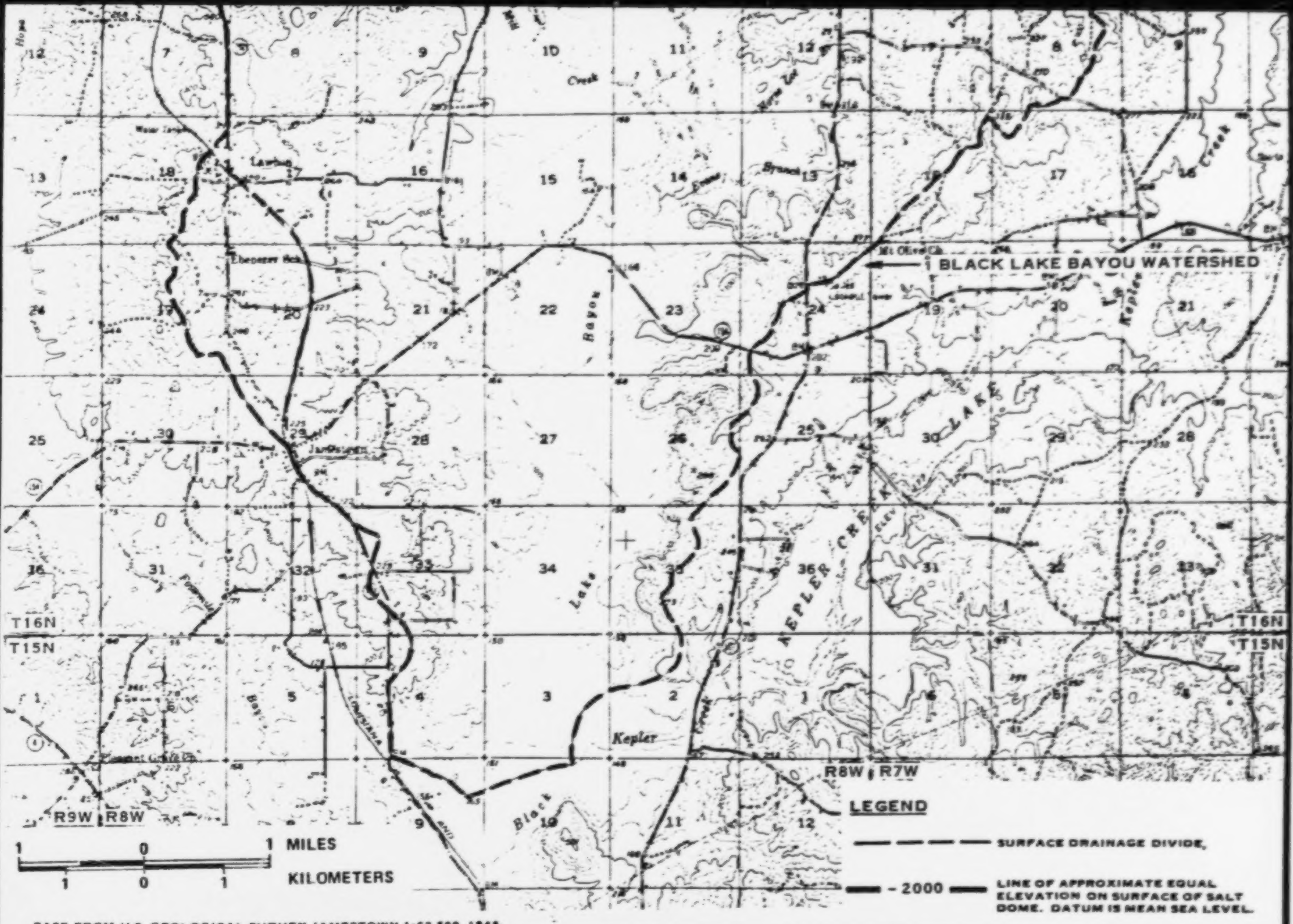
FIGURE 11-16



BASE FROM U.S. GEOLOGICAL SURVEY JAMESTOWN 1:62,500, 1948.

PREPARED [illegible] DATE [illegible]
REVISED RSM DATE 12/26/80
REVISED [illegible] DATE [illegible]
APPROVED GHF DATE 12/30/80

T-1213-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA . GEORGIA

NORTH LOUISIANA STUDY AREA
MAP SHOWING
TOPOGRAPHY AND DRAINAGE
VACHERIE DOME VICINITY

JOB NO. MV9700

FIGURE 11-16

1951 to 1968. Annual maximum discharge records are available for the period from 1974 to the present. The maximum flood of record at this station occurred on April 28, 1957. The maximum discharge was 90,624 l/sec (3,200 ft^3/sec), or approximately 2,351 l/sec (83 ft^3/sec) per square mile of drainage area. The corresponding stream stage was 65 meters (214.8 ft) MSL.

Discharge records are available for the Castor station for the periods from 1941 to 1957, and from 1958 to the present. Continuous discharge records are available for the period from 1941 to 1957. Annual maximum discharge records are available for the period from 1958 to the present. The maximum flood of record at this station occurred on April 3, 1945. The maximum discharge was 399,312 l/sec (14,100 ft^3/sec) or approximately 935 l/sec (33 ft^3/sec) per square mile of drainage area. The corresponding stream stage was 45 meters (148.2 ft) MSL.

11.3.1.1.3 Flood Plain Delineation - Flood plain delineation was based on the probable maximum flood for streams crossing the domal area. This flood was determined using:

(1) Published probable maximum precipitation values for the area

(2) Estimated hydrologic response characteristics of the watershed to the probable maximum precipitation

(3) The U.S. Department of Agriculture, Soil Conservation Services (SCS) flood-routing computer program published as Technical Report No. 20 (TR-20)

(4) The Army Corps of Engineers stream-backwater profile computer program published as HEC-2.

The general methodology involved the computation of peak discharges at several points on the stream channel, which would result from the probable maximum precipitation over the domal area. These peak discharges were then used to compute water surface profiles to delineate the flooded areas.

Maximum flooding on Bashaway Creek and its tributaries would inundate about 174 hectares (430 acres), or approximately 18 percent of the area defined by the surface projection of the -610-meter (-2,000-ft) -MSL salt dome contour. The area that would be inundated is shown in Figure 11-17.

It is unlikely that the area inundated by the probable maximum flood would exceed that computed here. Parameters not measured, but which were needed for the computations, were estimated to produce conservatively high volumes of runoff and stream depths.

11.3.1.2 Ground-Water Hydrology: The sequence of hydrogeologic units at Vacherie Dome is similar to that which occurs regionally. Upper Cretaceous deposits include the Tuscaloosa, Eagle Ford, Austin, Taylor and Navarro Groups. These are overlain by Tertiary deposits which include the Midway, Wilcox and Claiborne Groups. Quaternary alluvium and terrace deposits constitute the remainder and youngest of the stratigraphic sequence.

[redacted]

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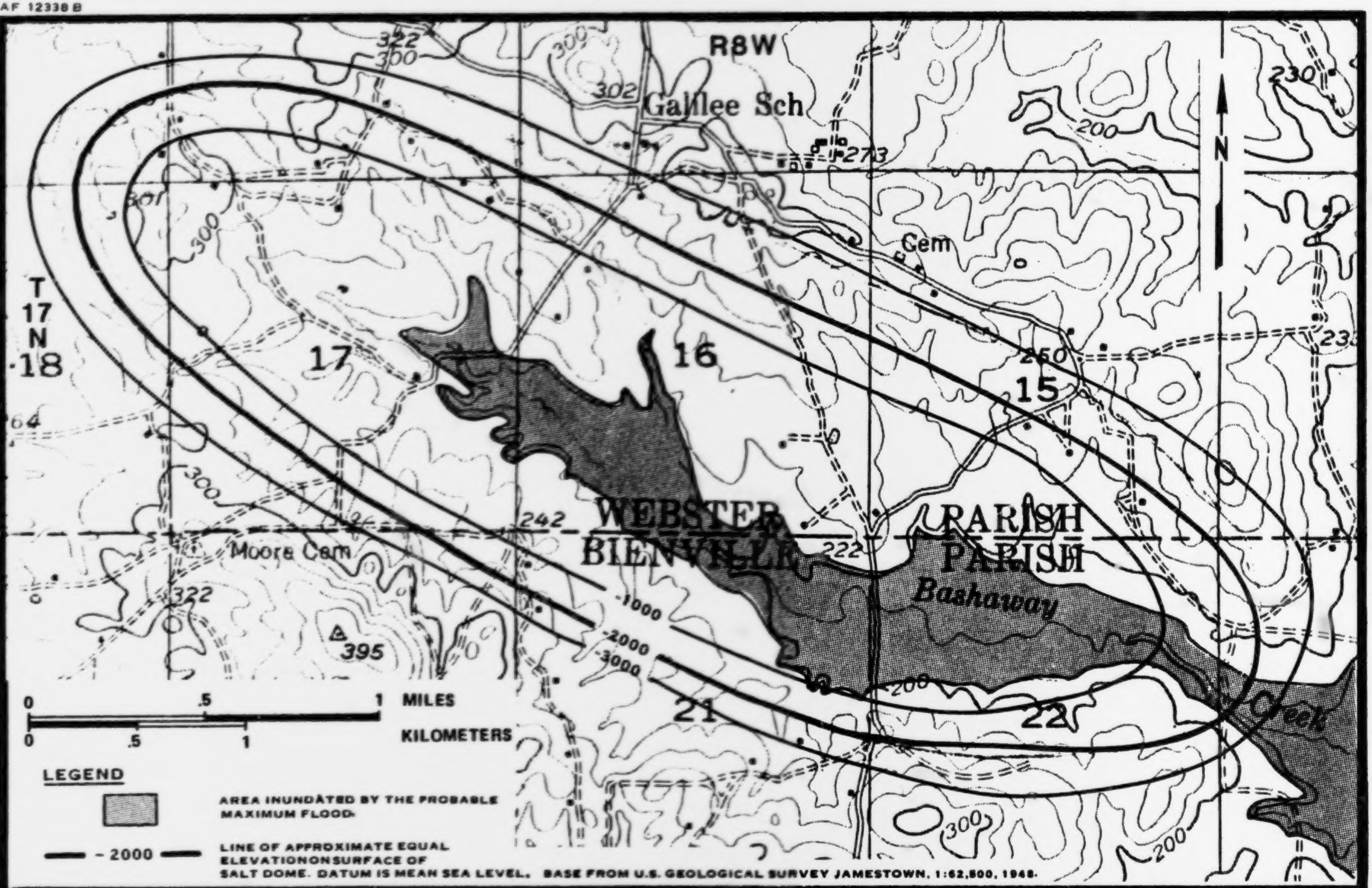


LEGEND

▨ AREA INUNDATED BY THE PROBABLE MAXIMUM FLOOD

— -2000 — LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY JAMESTOWN, 1:62,500, 1948.

FIGURE 11-17

PREPARED	[illegible]	DATE	[illegible]
REVISED	RSM	DATE	[illegible]
REVISED	[illegible]	DATE	[illegible]
APPROVED	GHF	DATE	12/30/80

T-1214-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM

GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA

MAP SHOWING AREA INUNDATED BY PROBABLE MAXIMUM FLOODING VACHERIE DOME VICINITY

JOB NO. MV9700

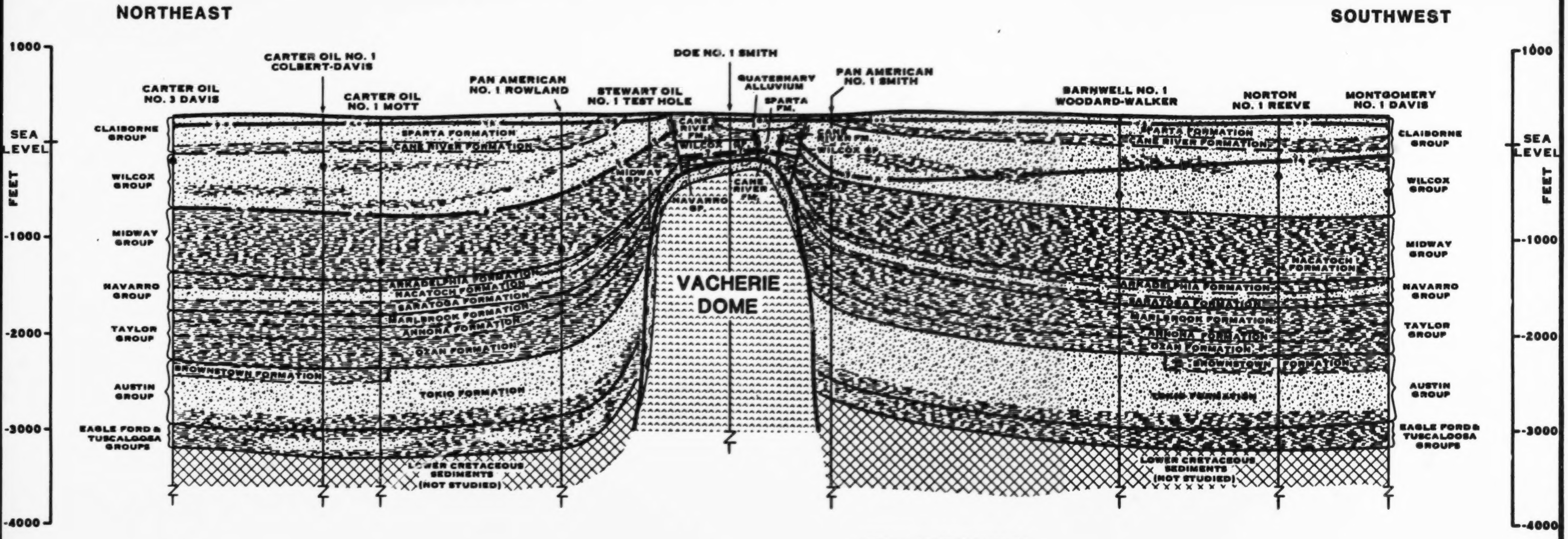
FIGURE 11-17

11.3.1.2.1 Domal Area Hydrogeology - The aquifer system of principal interest in the vicinity of Vacherie Dome is composed of the entire thickness of Upper Cretaceous, Tertiary, and Quaternary deposits (Figure 11-18).

Four separate test wells were drilled at Site LVH-6 for collecting hydrogeologic data near Vacherie Dome. One test well was completed in upper sand beds in the Austin Group, one in the Nacatoch Formation, one in the lower Wilcox Group, and one in the Sparta Formation. Aquifer testing of these formations yielded hydraulic conductivities of 0.4, 0.02, 2.3, and 30 m/day (1.4, 0.06, 7.6, and 100 ft/day), respectively. These data indicate that the undifferentiated deposits of the Austin Group have marginal water-transmitting properties, the Nacatoch Formation has poor water-transmitting properties, and the Wilcox Group and Sparta Formation have good water-transmitting properties in the vicinity of Site LVH-6.

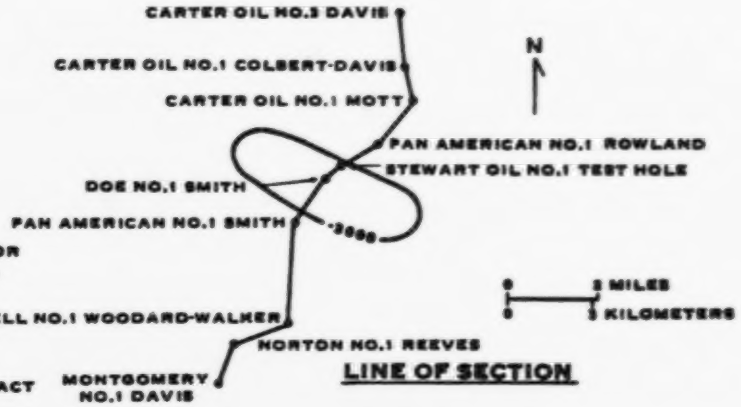
The salinity of the water varied between geologic deposits at the site. Water from the Sparta Formation was fresh. Water from the Wilcox Group was slightly saline. The total-dissolved content of this water was approximately 3,800 mg/l (3,800 ppm). Water from both the Nacatoch Formation and Austin Group was brine. The total dissolved-solids content of the waters from these units were approximately 215,000 and 125,000 mg/l (215,000 and 125,000 ppm), respectively.

Generalized flow directions at shallow depths in the groundwater reservoir less than about 30 meters (100 ft) in the vicinity of Vacherie Dome were determined from the shape of the water



VERTICAL EXAGGERATION X 4

4000 0 4000 FEET
1000 0 1000 METERS



LINE OF SECTION

LEGEND:

- ░ GEOLOGIC UNITS THAT MAY HAVE GOOD WATER TRANSMITTING PROPERTIES.
- ▒ GEOLOGIC UNITS THAT GENERALLY HAVE POOR WATER TRANSMITTING PROPERTIES.
- ▓ CAPROCK
- ⌒ SALT
- ● TOP OF LOGGED INTERVAL FOR GEOLOGIC INTERPRETATION.,
- ⫽ FAULT
- —— FORMATION CONTACT
- — — INFERRED FORMATION CONTACT
- —•—•— APPROXIMATE WATER TABLE CONFIGURATION
- —•— APPROXIMATE BASE OF FRESH WATER

PREPARED ______ DATE 9/28/81
REVISED ______ DATE 11/23/81
REVISED ______ DATE ______
APPROVED RSM DATE 9/28/81

T-1920-T

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

HYDROGEOLOGIC CROSS-SECTION THROUGH VACHERIE DOME

JOB NO. MV9700

FIGURE 11-18

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table (Figure 11-19). Water table contours were drawn using altitudes of streams and the general shape of the topography as guides. Flows are generally from areas of high water table elevations, under the north-south trending ridge that overlies the domal area, to areas of low elevations of the water table in the Black Lake Bayou and Bayou Dorcheat watersheds. The ridge is a local recharge area.

Horizontal flow directions in the Wilcox Group in the vicinity of the dome have been investigated by Martinez and others (1979). A potentiometric high area was identified in these deposits over the domal area (Figure 11-20). Flow is from this potentiometric high area toward potentiometric low areas away from the dome. The area around the dome is a local recharge area for the Wilcox Group. Intrusion of the salt mass has exposed the Wilcox Group where it is recharged.

Vertical flow directions between geologic deposits were estimated from an analysis of the vertical distribution of environmental heads (see Figure 11-12). Environmental heads at Site LVH-6 suggest that upward flow is occurring there from the Nacatoch Formation to the Wilcox Group. The head distribution also suggests that the Sparta Formation and Wilcox Group may act as a single hydrogeologic unit, and that the Nacatoch Formation and Austin Group may act as a single hydrogeologic unit in this area.

11.3.1.2.2 Ground-Water Flow Time Analysis - Ground-water velocities in geologic deposits are variable in the vicinity of Vacherie Dome. Ground-water velocities in deposits of the Wilcox

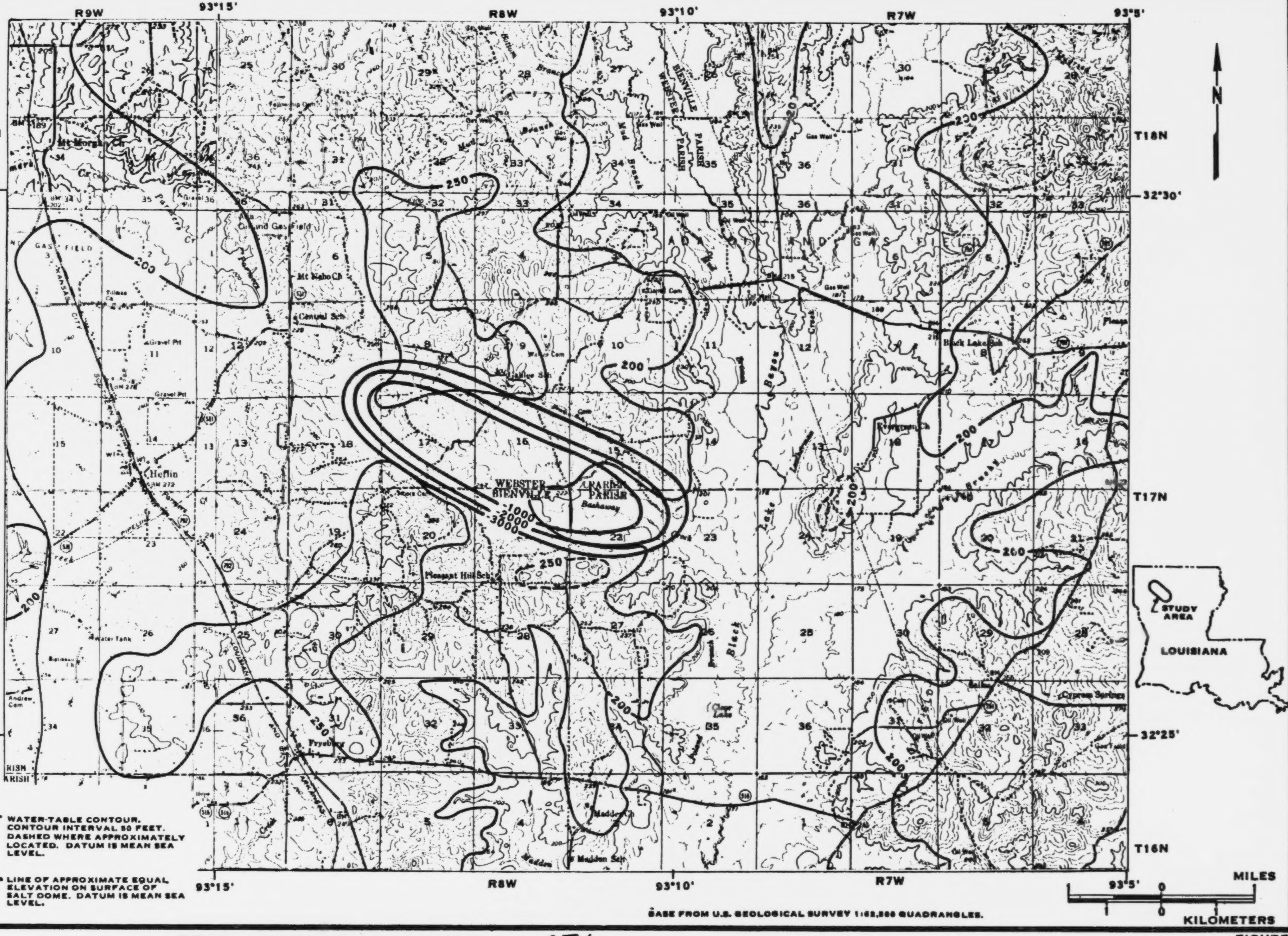
Group vary between about 30 and 24 m/yr (10 and 80 ft/yr) around the dome. The flow is away from the dome in all directions with the highest velocities to the south and the lowest to the west. The ground-water velocity in deposits of the Austin Group is approximately 2m/yr (8 ft/yr) at Site LVH-6 near the dome. Flow is generally southwesterly in these deposits. The ground-water velocity in the Nacatoch Formation is about 0.03 m/yr (0.1 ft/year) at Site LVH-6. Flow is generally northwestward there in this formation.

The average vertical ground-water flow time from various depths below the fresh-water base to the base of the fresh-water surface in the vicinity of Vacherie Dome was estimated (Slaughter, 1981). Vertical flow times, computed on the basis of available data and estimated parameters, varied between approximately 138,000 years from a point 152 meters (500 ft) to approximately 457,000 years from a point 652 meters (2,140 ft) below the base of fresh water (Figure 11-21). The vertical velocity averaged about 0.001 m/yr (0.004 ft/yr).

The flow time analysis suggests that ground water in the vicinity of Vacherie Dome can travel relatively long distances horizontally while only traveling short distances vertically during a given time period. The ratio of horizontal velocity in the Wilcox and Austin Groups to the estimated average vertical velocity in the vicinity of the dome is approximately 1,700 to 1.

11.3.1.3 Water Chemistry: The chemical composition of water in the vicinity of Vacherie Dome was investigated. Field parameters

[redacted]



LEGEND

—200— WATER-TABLE CONTOUR. CONTOUR INTERVAL 50 FEET. DASHED WHERE APPROXIMATELY LOCATED. DATUM IS MEAN SEA LEVEL.

—-3000— LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY 1:62,500 QUADRANGLES.

NORTH LOUISIANA STUDY AREA
MAP SHOWING GENERALIZED
WATER-TABLE
VACHERIE DOME VICINITY

JOB NO. MV9700

FIGURE 11-19

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED BSM DATE 12/26/80
REVISED DGF DATE 11/10/81
REVISED ______ DATE ______
APPROVED GHF DATE 12/30/80

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FIGURE 11-19

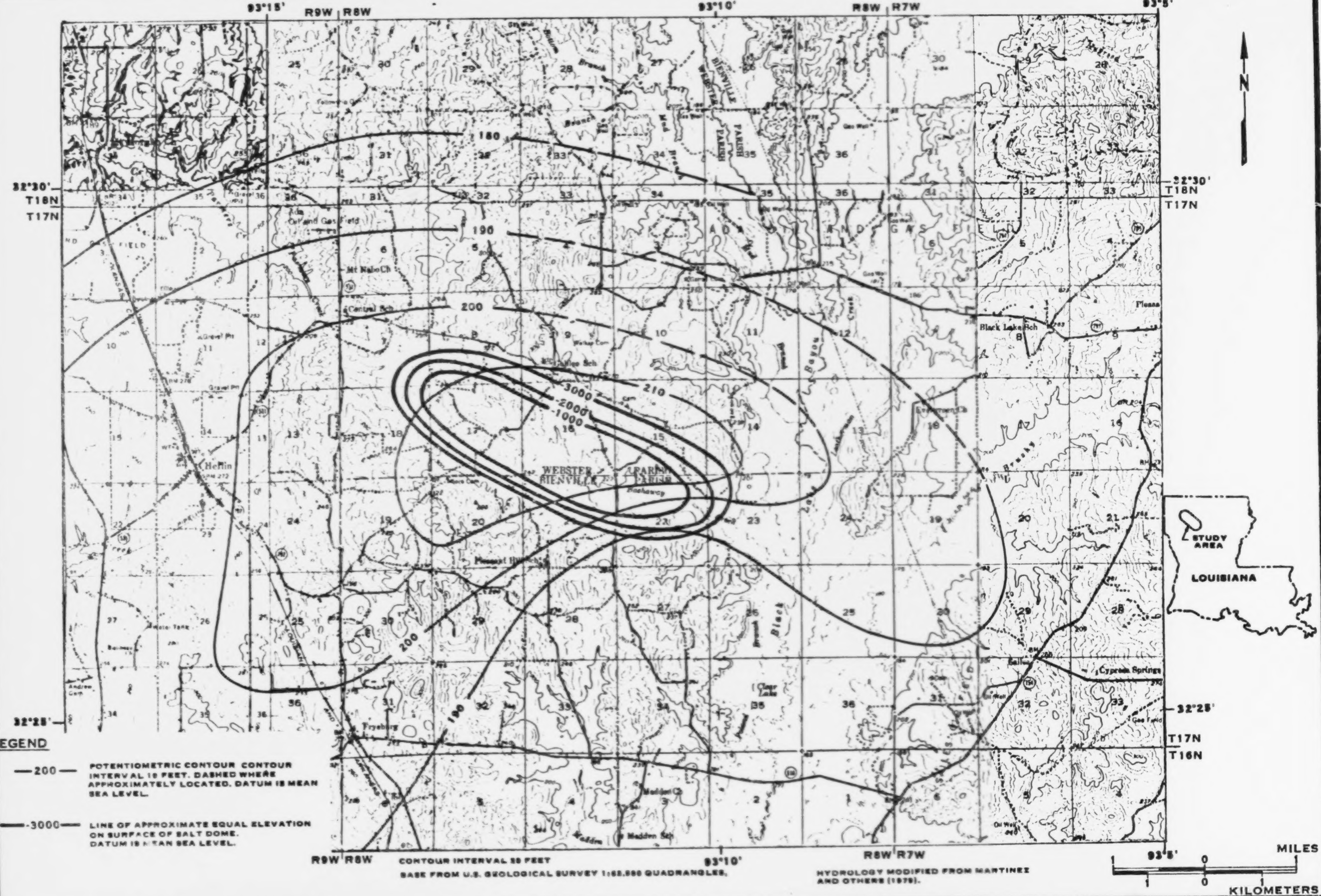
NORTH LOUISIANA STUDY AREA
MAP SHOWING POTENTIOMETRIC
SURFACE OF WILCOX GROUP
VACHERIE DOME VICINITY

FIGURE 11-20

JOB NO. MV9700

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA



LEGEND

—200— POTENTIOMETRIC CONTOUR CONTOUR INTERVAL 10 FEET. DASHED WHERE APPROXIMATELY LOCATED. DATUM IS MEAN SEA LEVEL.

—-3000— LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL.

CONTOUR INTERVAL 20 FEET
BASE FROM U.S. GEOLOGICAL SURVEY 1:62,500 QUADRANGLES.

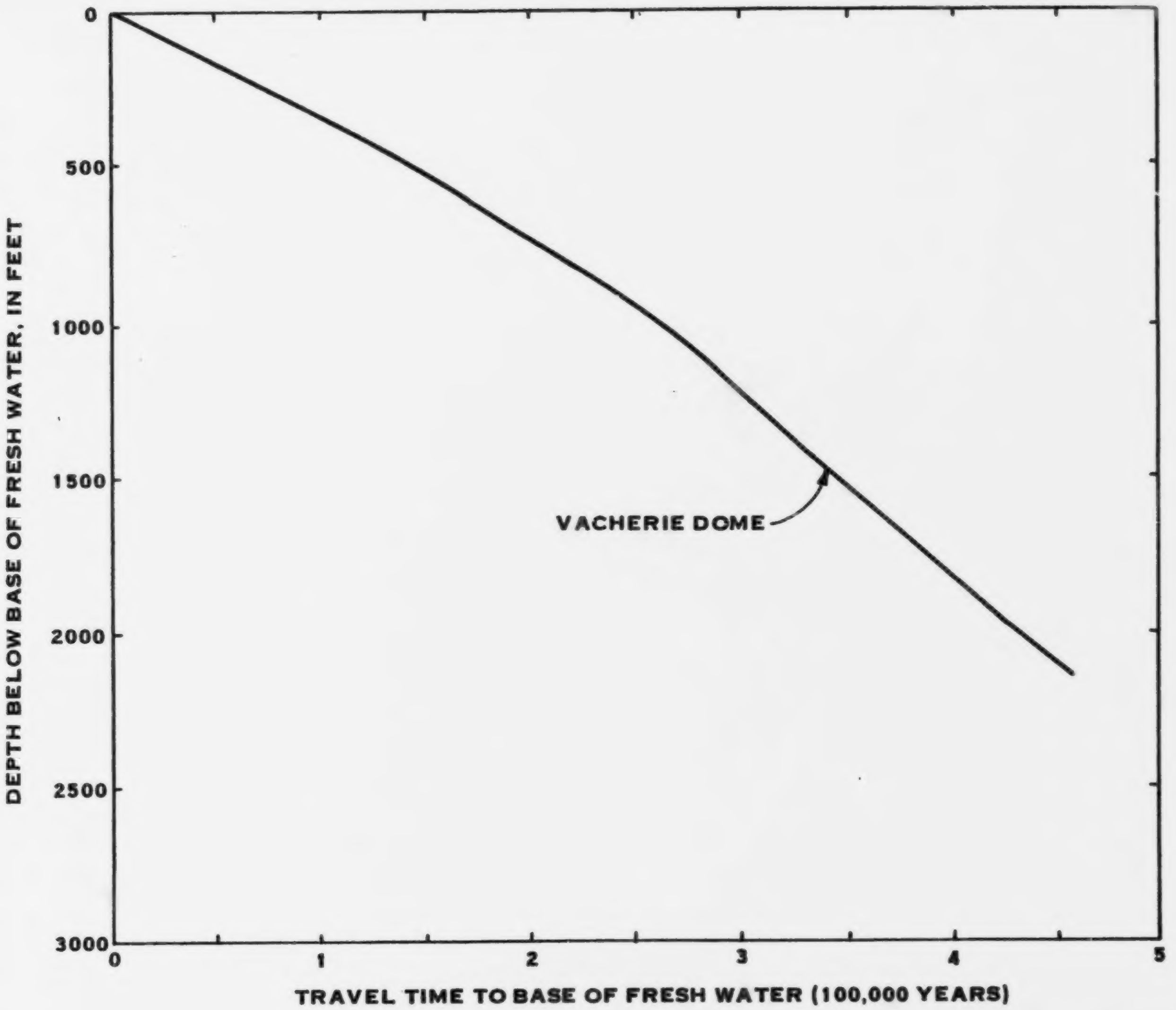
HYDROLOGY MODIFIED FROM MARTINEZ AND OTHERS (1979).

PREPARED RSM DATE 12/26/80
REVISED DATE
REVISED DATE
APPROVED GHF DATE 12/30/80

T-1629-1

FIGURE 11-20 [redacted]

BEST DOCUMENT AVAILABLE 272



PREPARED JEK DATE 11/20/81
REVISED ______ DATE ______
REVISED ______ DATE ______
APPROVED DW DATE 12/4/81

T-1229-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM

GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA

GRAPH OF TRAVEL TIME ALONG VERTICAL FLOW PATH TO DEPTH AT VACHERIE DOME

JOB NO. MV9700

FIGURE 11-21

FIGURE 11-21

TABLE 11-7

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF VACHERIE DOME

(Page 1 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Bashaway Creek	V1	06/24/80	23.6	3.0	51	5.6
		07/15/80[2]				
		07/30/80[2]				
		09/08/80[2]				
		10/13/80[2]				
		12/17/80[2]				
		03/31/81	15.3		60	5.7
		05/12/81	14.7	5.9	110	5.3
		08/20/81[2]				
Black Lake Bayou	V4	06/24/80	24.8	5.4	255	5.6
		07/15/80	27.8	2.2	113	6.6
		07/30/80	25.0		92	6.1
		09/08/80	26.2	3.9	88	6.5
		10/13/80[2]				
		12/17/80	8.5	6.6	44	6.1
		03/31/81	15.4	5.6	30	4.9
		05/12/81	16.8	5.8	170	5.2
		08/20/81	23.8	1.4	130	6.1
Black Lake Bayou	V7	06/24/80	25.5	5.6	424	5.9
		07/15/80	30.2		174	
		07/30/80[1]				
		09/09/80	24.2	1.4	208	6.8
		10/14/80[2]				
		12/17/80	9.5	6.7	150	5.5
		03/31/81	17.5	5.8	90	5.3
		05/12/81	16.4	5.9	190	5.5
		08/20/81	28.0	5.2	310	6.2

TABLE 11-7

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF VACHERIE DOME

(Page 2 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Black Lake Bayou	V17	06/24/80	26.8	5.8	140	5.9
		07/15/80	31.2		137	
		07/30/80	27.5		128	6.4
		09/09/80	26.6	5.2	41	6.4
		10/14/80	16.1		71	6.3
		12/17/80	10.3	9.8	55	6.2
		03/31/81	17.5	6.0	70	5.3
		05/12/81	17.5	6.4	340	5.7
		08/20/81	26.5	1.7	170	6.1
Black Lake Bayou	V18	06/24/80	26.8	5.3	121	5.8
		07/15/80	30.7		133	
		07/30/80	25.0		130	5.3
		09/09/80	26.6	5.3	42	6.2
		10/14/80	14.0		68	6.6
		12/17/80	9.9	8.9	58	6.0
		03/31/81	17.9	5.8	100	5.4
		05/12/81	18.0	6.1	140	5.9
		08/20/81	26.6	3.6	240	6.3
Brushy Creek	V19	06/24/80	26.0	5.3	80	5.5
		07/15/80	27.0	3.6	63	5.9
		07/30/80	25.0		130	5.3
		09/08/80	25.9	4.3	59	6.1
		10/13/80	17.9		56	6.2
		12/17/80	9.5	6.3	104	5.7
		03/31/81	16.4	5.4	90	4.7
		05/12/81	16.8	5.9	100	5.3
		08/20/81	23.9	3.2	110	5.0

TABLE 11-7

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF VACHERIE DOME

(Page 3 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/1)	SPECIFIC CONDUCTANCE (μmhos/cm)	pH (S.U.)
Fourmile Bayou	V15	06/24/80	25.5	6.2	71	6.2
		07/15/80	28.7		193	
		07/30/80	25.5		170	6.7
		09/09/80	23.8	5.3	84	6.4
		10/14/80	15.0		215	6.1
		12/17/80	8.8	9.4	184	6.5
		03/31/81	16.9	7.8	120	5.9
		05/12/81	15.4	5.4	120	6.4
		08/20/81	24.9	1.4	200	6.1
Fourmile Bayou	V16	06/24/80	26.2	3.8	78	6.1
		07/15/80	27.8	0.9	134	6.7
		07/30/80[1]				
		09/09/80	23.3	1.1	98	6.8
		10/14/80	12.8		109	6.5
		12/17/80	8.6	6.1	109	6.5
		03/31/81	16.8	6.7	60	5.6
		05/12/81	16.2	6.5	70	6.0
		08/20/81	23.3	1.0	120	6.5
Hope Creek	V14	06/24/80	24.6	3.0	86	5.6
		07/15/80	26.2	0.8	123	6.0
		07/30/80	24.5		88	5.8
		09/08/80	25.1	2.1	121	6.2
		10/13/80	15.6		89	5.7
		12/17/80	9.7	5.4	97	5.8
		03/31/81	15.2		60	5.2
		05/12/81	15.8	6.6	50	5.5
		08/20/81	23.3	0.5	170	5.5

TABLE 11-7

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF VACHERIE DOME

(Page 4 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (μmhos/cm)	pH (S.U.)
Black Lake Bayou	V10	06/24/80	23.9	5.9	61	5.2
		07/15/80	27.4	1.8	121	6.6
		07/30/80	24.5		128	6.5
		09/08/80	27.6	5.6	804	6.0
		10/13/80	14.0		968	6.2
		12/17/80	8.5	4.8	147	6.1
		03/31/81	16.1	5.8	110	5.4
		05/12/81	15.5	6.4	90	5.5
		08/20/80	23.8	2.7	170	6.2
Leatherman Creek	V11	06/24/80	24.0	5.2	133	5.2
		07/15/80	27.6	2.3	244	6.4
		07/30/80	24.5		230	6.6
		09/08/80	26.2	3.3	232	6.9
		10/13/80[2]				
		12/17/80	8.4	5.1	391	6.6
		03/31/81	16.0	5.5	160	5.8
		05/12/81	15.6	5.0	120	5.5
		08/20/81	23.5	2.1	270	6.2
Madden Mill Creek	V6	06/24/80	25.6	4.6	38	5.5
		07/15/80	26.9	4.8	39	5.9
		07/30/80	24.5		44	5.9
		09/08/80	24.8	6.2	31	6.8
		10/13/80	13.8		16	6.2
		12/17/80	8.8	8.6	33	5.7
		03/31/81	15.3	6.0	20	5.2
		05/12/81	15.0	6.4	25	5.4
		08/20/81	22.9	4.4	30	6.0

TABLE 11-7

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF VACHERIE DOME

(Page 5 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Madden Mill Creek	V3	06/24/80	28.3	2.2	41	5.2
		07/15/80	27.7	0.3	65	5.6
		07/30/80	26.0		68	5.8
		09/08/80	24.3	0.7	70	5.8
		10/13/80	15.9		24	24
		12/17/80	9.1	9.1	37	5.8
		03/31/81	16.6	5.1	30	5.1
		05/12/81	15.3	3.0	30	5.3
		08/20/81	23.3	0.3	50	5.2
Mud Branch	V12	06/24/80	25.7	5.6	66	5.1
		07/15/80	27.7	5.1	87	5.3
		07/30/80	25.0		78	5.4
		09/08/80	27.6	5.1	95	5.6
		10/13/80	17.1		71	5.8
		12/17/80	9.8	9.0	55	5.7
		03/31/81	15.4	6.8	30	5.1
		05/12/81	16.2	6.6	30	5.5
		08/20/81	24.6	3.8	60	5.2
Mud Branch	V9	06/24/80	24.6	4.3	133	5.4
		07/15/80	27.6	0.7	1090	6.2
		07/30/80	25.5		920	5.9
		09/08/80	25.6	3.4	2030	6.3
		10/13/80	15.2		768	5.9
		12/17/80	8.9	5.8	194	5.9
		03/31/81	16.4	1.8	160	5.2
		05/12/81	15.6	3.0	130	5.2
		08/20/81	24.1	0.5	210	5.5

TABLE 11-7

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF VACHERIE DOME

(Page 6 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Parmers Creek	V13	06/24/80	23.0	5.4	140	5.2
		07/15/80	24.6	5.1	38	6.1
		07/30/80	23.0		480	5.0
		09/08/80	24.2	4.7	40	5.8
		10/13/80	14.4		27	6.3
		12/17/80	9.4	8.0	57	5.7
		03/31/81	15.2	5.8	50	4.7
		05/12/81	14.6	7.1	940	5.1
		08/20/81	21.7	2.9	170	5.1
Parmers Creek	V20	06/24/80	24.4	4.8	119	5.0
		07/15/80	25.9	4.9	43	5.9
		07/30/80	24.5		440	5.1
		09/08/80	25.6	5.8	42	6.4
		10/13/80	15.7		41	6.8
		12/17/80	9.3	8.7	95	6.1
		03/31/81	16.2	5.3	90	4.8
		05/12/81	15.4	6.2	430	4.9
		08/20/81	23.0	5.7	200	4.5
Black Lake Bayou	V5	06/24/80	24.5	5.6	227	5.6
		07/15/80	28.7	1.5	182	6.3
		07/30/80	25.5		190	6.6
		09/08/80	26.4	2.2	231	6.7
		10/13/80[2]				
		12/17/80	8.8	7.0	222	5.8
		03/31/81	17.1		120	5.4
		05/12/81	16.7	5.7	170	5.4
		08/20/81	25.0	0.9	230	6.2

TABLE 11-7

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF VACHERIE DOME

(Page 7 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Black Lake Bayou	V8	06/24/80	25.6	5.7	283	6.0
		07/15/80[2]				
		07/30/80[2]				
		09/09/80[2]				
		10/14/80[2]				
		12/17/80	11.0	4.5	30	5.1
		03/31/81	17.8	5.4	90	5.2
		05/12/81	16.4	5.9	210	5.5
		08/20/81[2]				
Kepler Creek	V21	09/09/80	27.2	6.4	40	6.2
		10/14/80	15.2		31	6.6
		12/17/80	11.4	10.1	34	6.1
		03/31/81	17.4	7.5	50	5.1
		05/12/81	17.4	7.4	30	5.8
		08/20/81	24.3	5.7	40	6.4

---

[1] Stagnant pools, no flow

[2] Dry

of water temperature, dissolved oxygen, conductance, and pH were measured at selected sites on streams in the vicinity of the dome (see Figure 11-2). These data were integrated with ground-water chemistry data collected by LETCo and ground- and surface-water chemical data collected by USGS.

Results of field measurements at 20 surface-water sampling sites around the dome indicate that surface waters vary greatly in dissolved-solids concentration. Dissolved-solids concentrations, estimated from field measurements of specific conductance (Table 11-7), were usually less than 200 mg/l (200 ppm) but ranged as high as 2,030 mg/l (2,030 ppm). Variations by a factor of 10 were detected in dissolved-solids concentrations at Sites V9, V10, V13, and V20 during the sampling period. These variations do not appear to be related to seasonal variations in flow rates. Further investigation is needed to identify reasons for this variability.

The chloride content of the water in Bashaway Creek varies considerably in the vicinity of the dome. Water samples analyzed by USGS (Ryals and Hosman, 1980) indicated a downstream increase in chloride content of the water. Additional sampling is necessary to better define and delineate this occurrence in order to evaluate the processes responsible for this apparent anomaly.

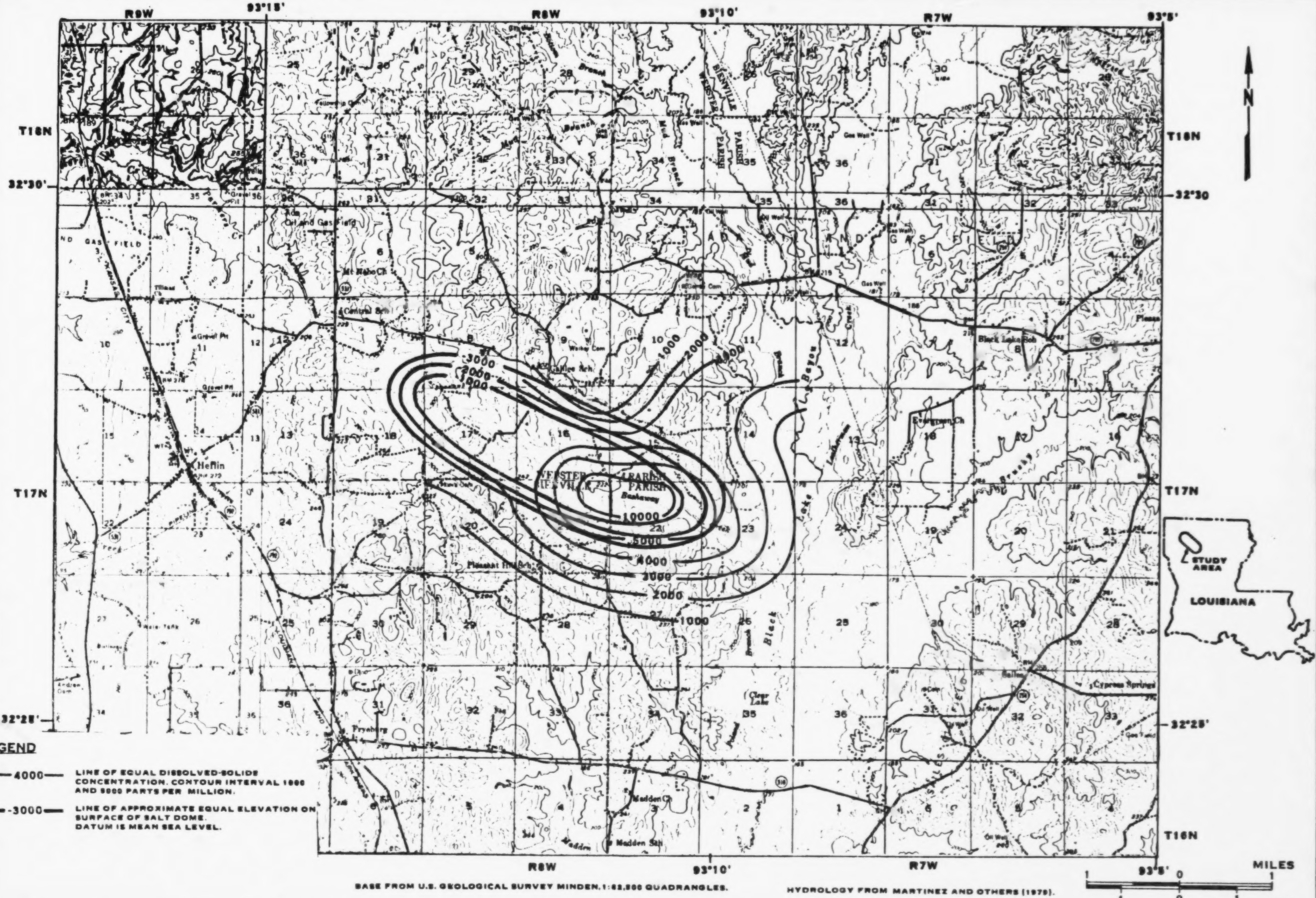
The chemical character of water in the Sparta Formation and overlying deposits in the vicinity of Vacherie Dome is similar to the regional water chemistry of these aquifers. The water is a sodium-bicarbonate type with low concentrations of dissolved solids. Data for concentrations of dissolved constituents correlated well with those of regional well sites.

The salinity of water in the Wilcox Group in the vicinity of Vacherie Dome has been investigated by Martinez and others (1979). High concentrations of total dissolved solids were identified in the water in these deposits on the east side of the dome (Figure 11-22). This salinity concentration has tentatively been attributed to the dissolution of domal salt stock by fresh water.

An anomalous salinity distribution was observed in deeper deposits at Site LVH-6 near Vacherie Dome. The total dissolved-solids content of water from the Nacatoch Formation was found to be approximately 1.7 times greater than that of water from the underlying Austin Group. Sufficient data to explain the reason for this anomaly are lacking.

11.3.1.4 Relationship of Surface Water to Ground Water: Quaternary alluvium is the predominant surficial geologic unit exposed in the area. The base flow of Bashaway Creek and small streams in the vicinity of the dome is sustained by ground-water flow, generally from the alluvial material. The alluvial material may, however, receive water from the Tertiary aquifers, probably from the Sparta Formation (Hosman, 1978).

Low flow of streams in the vicinity of Vacherie Dome, expressed as the 7-day, 2-year low flow, is an indicator of hydrogeologic properties of the Sparta Formation.



LEGEND

—4000— LINE OF EQUAL DISSOLVED-SOLIDS CONCENTRATION. CONTOUR INTERVAL 1000 AND 5000 PARTS PER MILLION.

—-3000— LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY MINDEN, 1:62,500 QUADRANGLES.

HYDROLOGY FROM MARTINEZ AND OTHERS (1979).

NORTH LOUISIANA STUDY AREA
SALINITY OF WATER IN WILCOX
GROUP VACHERIE DOME
VICINITY

JOB NO. MV9700

FIGURE 11-22

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED RSM DATE 12/12/80
REVISED JP DATE 11/13/81
REVISED DATE
APPROVED GHF DATE 12/30/82

T-1630-1

FIGURE 11-22

BEST DOCUMENT AVAILABLE

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The low-flow data for streams in the vicinity of Vacherie Dome that derive water from the Sparta Formation suggest that the hydraulic properties of the Sparta Formation in this area are relatively high and that local recharge is good. The 7-day, 2-year low flow for Brushy Creek near Liberty (07352750), Castor Creek at Castor (07352700), and Kepler Creek near Sparta (07352400), are, respectively, 0.28, 4.53, and 5.66 l/sec (0.01, 0.16 and 0.20 ft/sec) per square mile of drainage area (Speer and others, 1966). These values are typical of those for other streams in the study area which derive their low flow from the Sparta Formation.

11.3.1.5 Water and Aquifer Use: Vacherie Dome is situated in southern Webster and northern Bienville Parishes. Water use is substantially greater in Webster Parish than in Bienville Parish. In 1975, water use in Webster Parish was 48 million l/day (12.6 million gal/day) from ground-water supplies and 67 million l/day (17.63 million gal/day) from surface-water supplies (Table 11-4). Water use in Bienville Parish was 6.32 and 0.34 million l/day (1.67 and 0.09 million gal/day), respectively, from ground- and surface-water sources (Cardwell and Walter, 1979).

The city of Minden, Louisiana, located in southern Webster Parish, is the largest user of water near Vacherie Dome. Surface water supplies are withdrawn from Bayou Dorcheat and utilized for a variety of industrial and cooling purposes. Most water supply wells serving Minden withdraw water from the Sparta Formation. Withdrawals are heavy and have induced a cone of depression in the potentiometric surface of the Sparta Formation in the Minden area (Cardwell and Walter, 1979) (Figure 11-9).

Rural water withdrawals are typical of other parts of the study area. Numerous domestic and other low-yield wells with capacities of less than 1.26 l/sec (20 gal/min), are completed in the Sparta Formation or the Quaternary alluvium and terrace deposits and are used for water supply.

Three disposal wells are located near Vacherie Dome (Figure 11-15). These wells discharge waste into the Nacatoch Formation southeast of the Dome at depths exceeding 533 meters (1,750 ft) below the ground surface. Quantities of waste disposed were variable, but averaged 460,000 barrels per year in 1977.

11.3.2 RAYBURNS DOME: Surface- and ground-water hydrologic data were collected in the vicinity of Rayburn's Dome. Ground-water hydrologic data were collected at data-collection Site LRH-13, located approximately 1.6 km (1 mi) south of the dome. Surface-water chemical and physical parameters were collected at 19 locations around the dome (Figure 11-2).

11.3.2.1 Surface-Water Hydrology: Rayburn's Dome is located along the drainage divide between Fouse Bayou and Muddy Creek watersheds, about 21 km (13 mi) west of Jonesboro, Louisiana (Figure 11-23). Both streams are tributaries to the Dugdemona River.

11.3.2.1.1 Domal Area Drainage - Fouse Bayou and Muddy Creek watersheds are characterized by gently rolling to hilly topography with relatively wide alluviated flood plains. Elevations in these watersheds range from 37 to 98 meters (120 to 320 ft) MSL. The drainage pattern of both streams is dendritic, with streambed slopes ranging from greater than 8 m/km (40 ft/mi) in the headwaters to approximately 0.9 m/km (5 ft/mi) near the mouth. Fouse Bayou drains 65 km^2 (25.1 mi^2) and Muddy Creek drains 46 km^2 (17.9 mi^2).

11.3.2.1.2 Historical Floods - There are no published records of floods for Fouse Bayou or Muddy Creek watersheds.

The nearest USGS stream-gauging stations (Figure 11-13) are on Dugdemona River near Jonesboro (Station #07371500), approximately 1.6 km (1 mi) upstream of the confluence with Muddy Creek (Figure 11-23), and on Dugdemona River near Winnfield (Station #07372000), approximately 31 km (19 mi) downstream from the confluence with Fouse Bayou (Figures 11-13 and 11-23).

Discharge records are available for the Jonesboro station for the periods from October, 1938 to September, 1957, and from November, 1957 to the present. Continuous discharge records are available for the period from 1938 to 1957. Annual maximum discharge records are available for the period from 1957 to the present. The maximum flood of record at this site occurred on January 1, 1945. The maximum discharge for this flood was 866,592 l/sec (30,600 ft^3/sec), or approximately 2,436 l/sec

(86 ft^3/sec) per square mile of drainage area. The corresponding stream stage was 41.6 meters (136.4 ft) MSL.

Continuous discharge records are available for the Winnfield station for the period from April, 1939 to the present. The maximum flood of record at this site occurred on May 19, 1953. The maximum discharge for this flood was 767,472 l/sec (27,100 ft^3/sec), or approximately 1,161 l/sec (41 ft^3/sec) per square mile of drainage area. The corresponding stream stage was 31.9 meters (104.9 ft) MSL.

11.3.2.1.3 Flood Plain Delineation - Flood plain delineation was based on the probable maximum flood for streams which cross the domal area. The probable maximum flood was determined using:

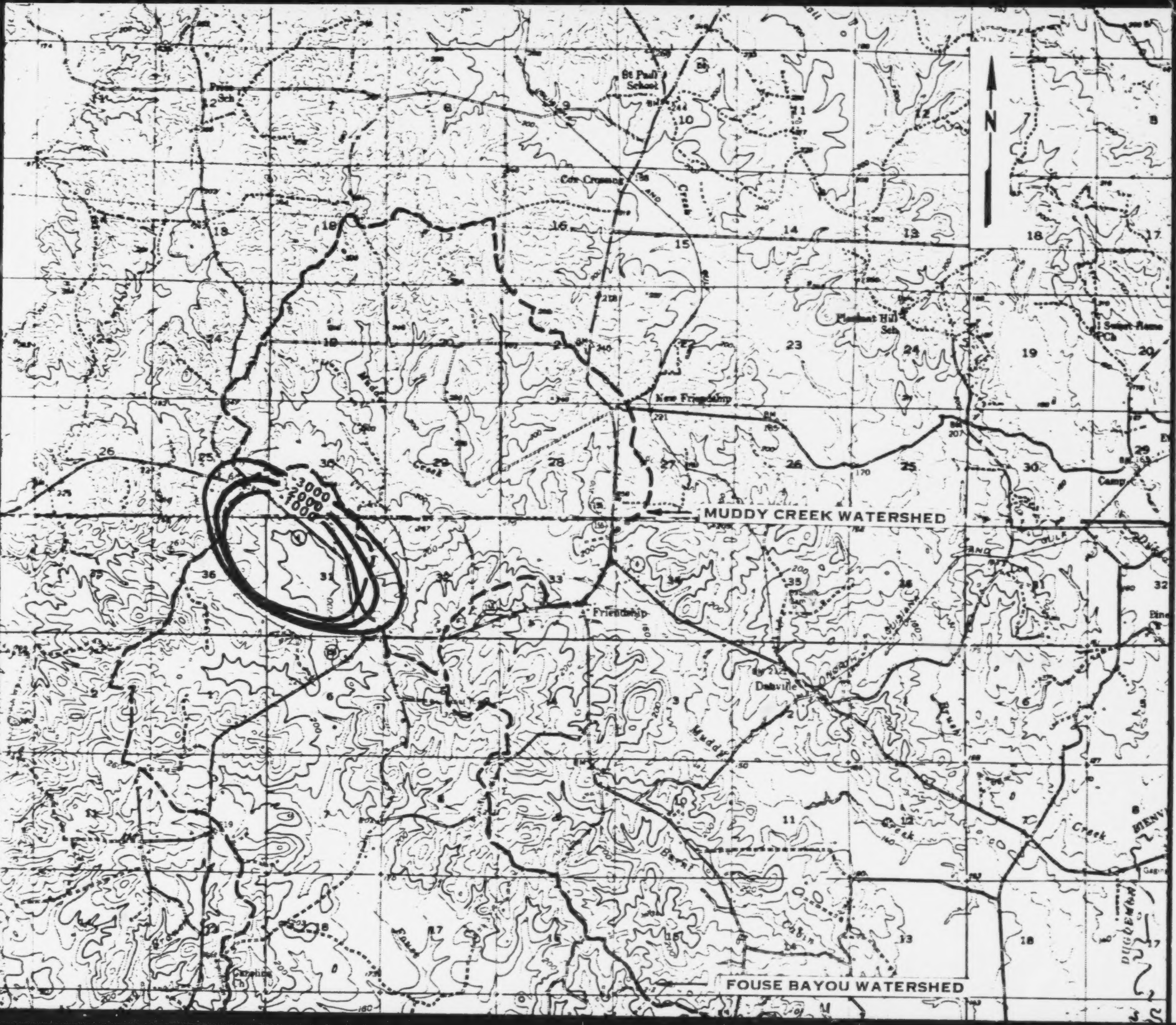
(1) Published probable maximum precipitation values for the area

(2) Estimated hydrologic response characteristics of the watershed to the probable maximum precipitation

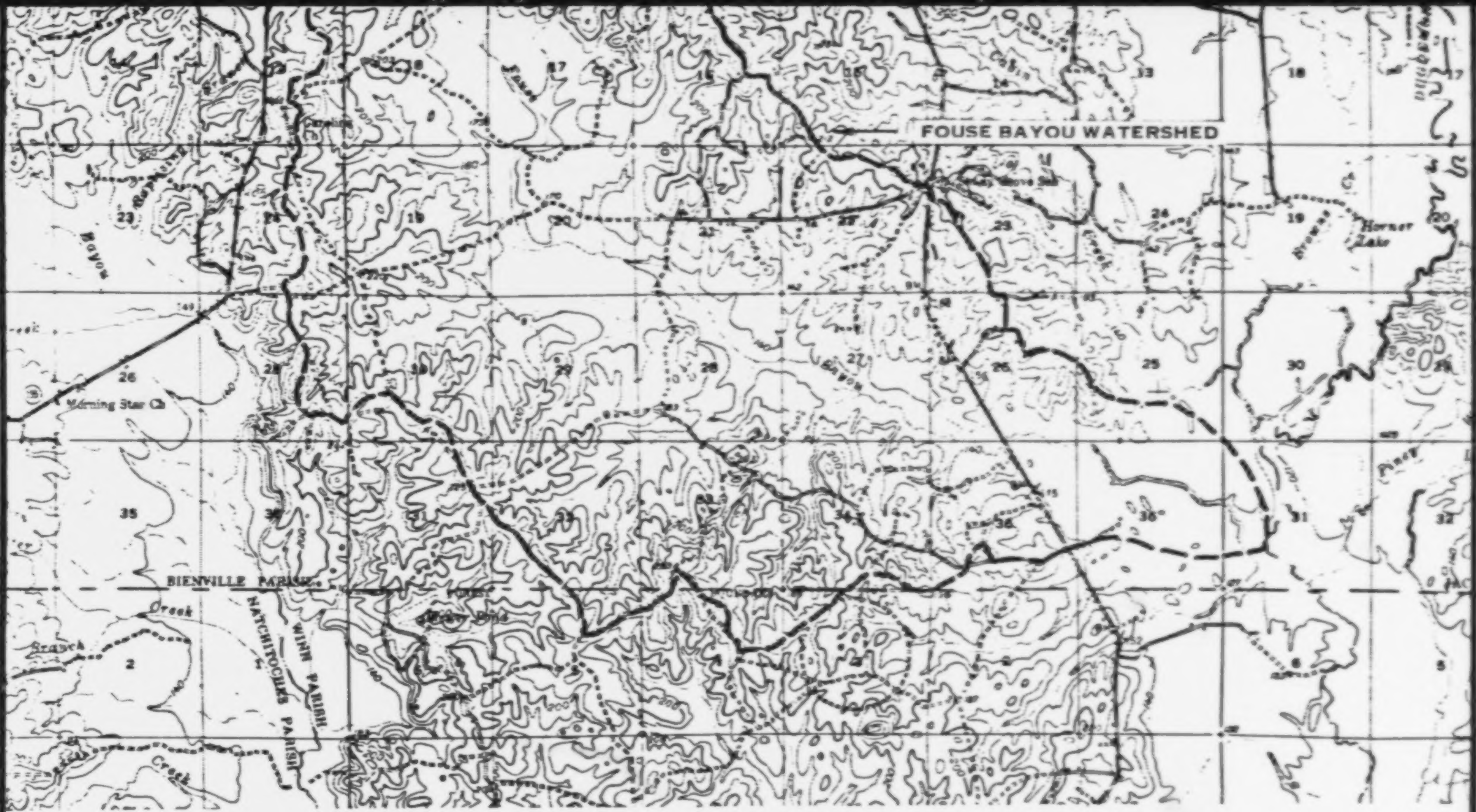
(3) The U.S. Department of Agriculture, Soil Conservation Services (SCS) flood-routing computer program published as Technical Report No. 20 (TR-20)

(4) The Army Corps of Engineers stream-backwater profile computer program published as HEC-2.

The general methodology involved the computation peak discharges at several points on the stream channels, which would result from the probable maximum precipitation over the domal area. These peak discharges were then used to compute water surface profiles to delineate the flooded areas.


N
St Paul School
Cox Crossing
Pleasant Hill Sch
New Friendship
Muddy Creek
3000
2000
1000
MUDDY CREEK WATERSHED
Friendship
Muddy
FOUSE BAYOU WATERSHED

BEST DOCUMENT AVAILABLE



LEGEND

— — — — — — SURFACE DRAINAGE DIVIDE.

━━ -2000 ━━ LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL.

1 0 1 MILES

1 0 1 KILOMETERS

CONTOUR INTERVAL 20 FEET

DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY 1:62,500 QUADRANGLES.

288A

PREPARED R-SIM DATE 7-2-80

REVISED RSM DATE 12/26/80

REVISED [illegible] DATE [illegible]

APPROVED GHF DATE 12/30/80

T-1216-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA
MAP SHOWING TOPOGRAPHY AND DRAINAGE
RAYBURNS DOME VICINITY

JOB NO. MV 9700

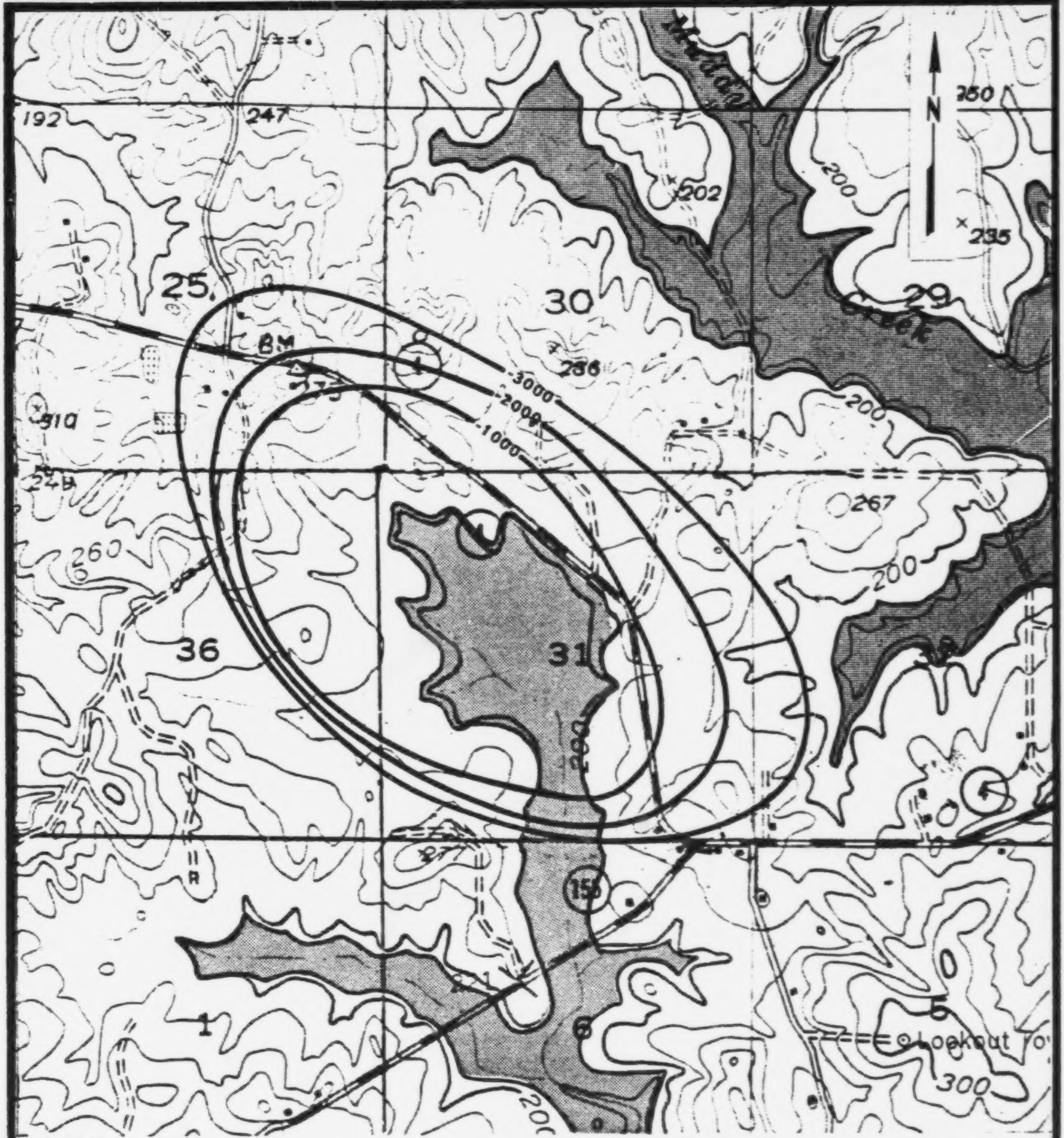
FIGURE 11-23

Maximum flooding of streams which cross the domal area would inundate about 63 hectares (155 acres), or approximately 20 percent of the area defined by the surface projection of the -610-meter (-2,000-ft) -MSL salt dome contour. This flooding represents probable maximum flooding of the Fouse Bayou and Muddy Creek watersheds (Figure 11-24). Parameters which were not measured, but needed for the computations, were estimated to produce conservatively high volumes of runoff and stream depths.

11.3.2.2 Ground-Water Hydrology: The sequence of hydrogeologic units at Rayburn's Dome is similar to that which occurs regionally. Upper Cretaceous deposits include the Tuscaloosa, Eagle Ford, Austin, Taylor, and Navarro Groups. These are overlain by Tertiary deposits which include the Midway, Wilcox, and Claiborne Groups. Quaternary alluvium and terrace deposits constitute the remainder of the stratigraphic sequence.

11.3.2.2.1 Domal Area Hydrogeology - The aquifer system of interest in the vicinity of Rayburn's Dome is composed of Upper Cretaceous, Tertiary, and Quaternary deposits above the undifferentiated Tuscaloosa and Eagle Ford Groups (Figure 11-25).

Three separate test wells were drilled at Site LRH-13 for the purpose of collecting hydrogeologic data near Rayburn's Dome. Two test wells were completed in the Wilcox Group (upper and lower) and one in the Sparta Formation. Aquifer testing of these formations yielded average hydraulic conductivities of 0.1 m/day (0.5 ft/day) for deposits in the lower part of the Wilcox Group,



LEGEND

▨ AREA INUNDATED BY THE PROBABLE MAXIMUM FLOOD

— -2000 — LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL.

0 .5 1 MILES

0 .5 1 KILOMETERS

BASE FROM U.S. GEOLOGICAL SURVEY BIENVILLE 1:62,500, 1947, AND GOLDONNA 1:62,500, 1957.

PREPARED [illegible] DATE [illegible]
REVISED RSM DATE [illegible]
REVISED [illegible] DATE [illegible]
APPROVED GHF DATE [illegible]

T-1217-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM

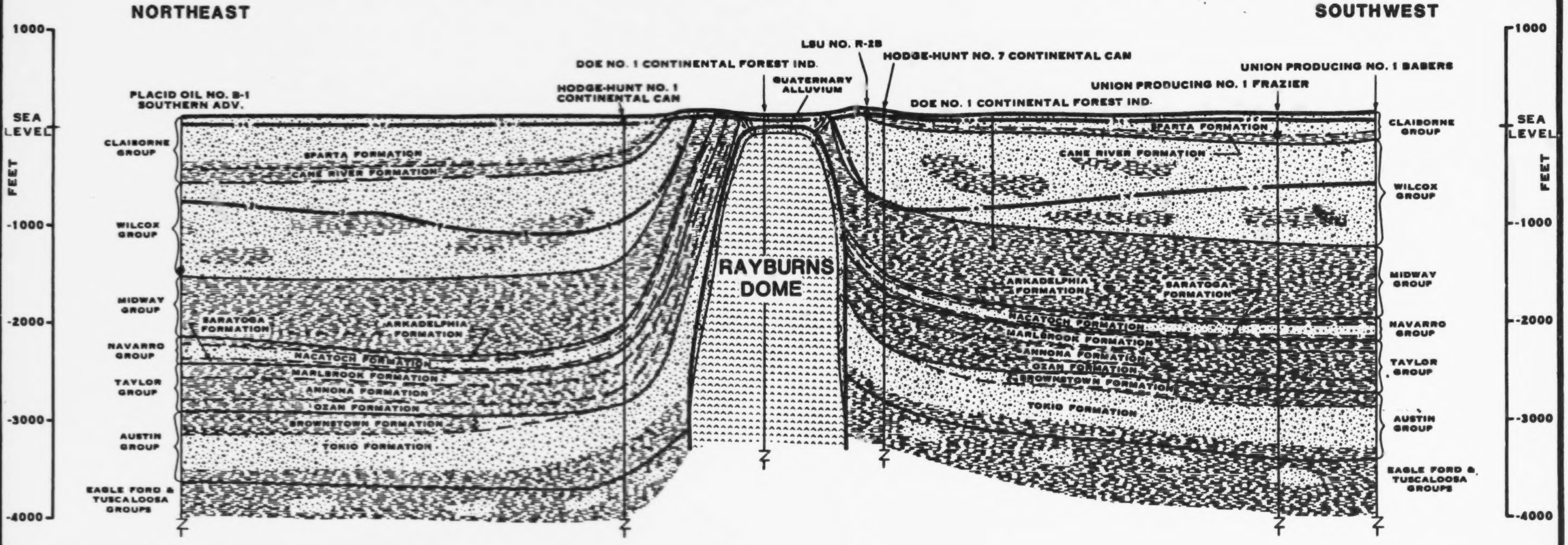
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA . GEORGIA

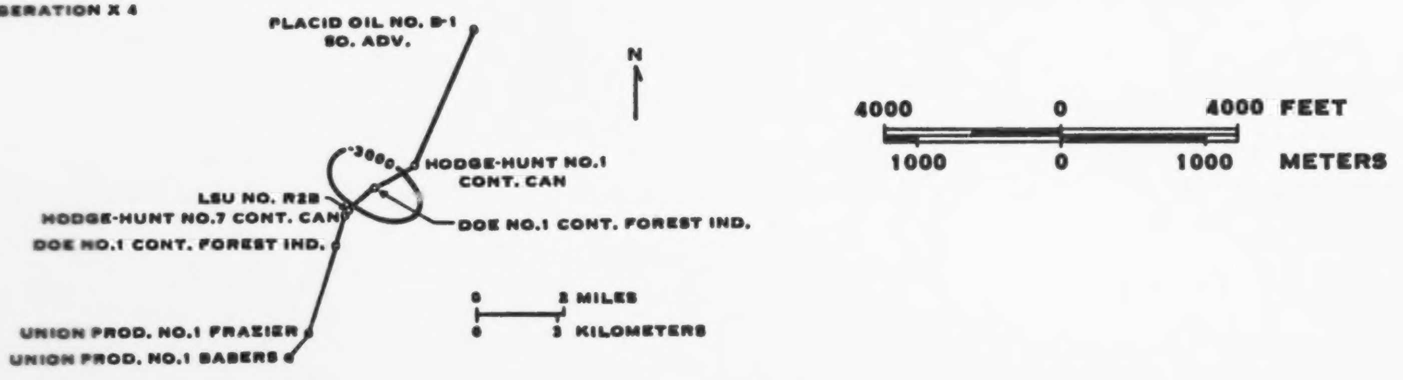
NORTH LOUISIANA STUDY AREA
MAP SHOWING AREA INUNDATED BY PROBABLE MAXIMUM FLOODING
RAYBURNS DOME VICINITY

JOB NO. MV9700

FIGURE 11-24



VERTICAL EXAGGERATION X 4


PLACID OIL NO. B-1 SO. ADV.
-3000
HODGE-HUNT NO.1 CONT. CAN
LSU NO. R2B
HODGE-HUNT NO.7 CONT. CAN
DOE NO.1 CONT. FOREST IND.
DOE NO.1 CONT. FOREST IND.
UNION PROD. NO.1 FRAZIER
UNION PROD. NO.1 BABERS
N
0 2 MILES
0 3 KILOMETERS
4000 0 4000 FEET
1000 0 1000 METERS

LINE OF SECTION

LEGEND

▒	GEOLOGIC UNITS THAT MAY HAVE GOOD WATER TRANSMITTING PROPERTIES
▓	GEOLOGIC UNITS THAT GENERALLY HAVE POOR WATER TRANSMITTING PROPERTIES
▨	CAPROCK
░	SALT
●	TOP OF LOGGED INTERVAL FOR GEOLOGIC INTERPRETATION
⫽	FAULT
——	FORMATION CONTACT
— —	INFERRED FORMATION CONTACT
—•—•	APPROXIMATE WATER TABLE CONFIGURATION
—·—	APPROXIMATE BASE OF FRESH WATER

PREPARED	LRR	DATE	9/28/81
REVISED	DAP	DATE	11/30/81
REVISED		DATE	
APPROVED	RSM	DATE	9/28/81

T-1921-0

NATIONAL WASTE TERMINAL
STORAGE PROGRAM
GEOLOGIC EVALUATION GULF
COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

HYDROGEOLOGIC CROSS-SECTION
THROUGH RAYBURNS DOME

JOB NO. MV9700

FIGURE 11-25

BEST DOCUMENT AVAILABLE 291

2.2 m/day (7.3 ft/day) for deposits in the upper part of the Wilcox Group, and 0.6 m/day (1.9 ft/day) for deposits in the Sparta Formation. These data indicate that, in the vicinity of Site LRH-13, the Sparta Formation and deposits in the lower part of the Wilcox Group have marginal water-transmitting properties, and deposits in the upper part of the Wilcox Group have good water-transmitting properties. Water pumped from the test wells at Site LRH-13 was fresh.

Generalized flow directions at shallow depths in the ground-water reservoir (less than about 30 meters (100 ft)) in the vicinity of Rayburn's Dome were determined from the shape of the water table (Figure 11-26). Water table contours were drawn by using altitudes of streams and the general shape of the topography as guides. Flows are generally from areas of high water table elevations, under the north-south trending ridge between the Saline Bayou and Dugdemona River watersheds, to areas of low elevations of the water table in these watersheds. Saline Bayou and Dugdemona River, and their tributaries, are local discharge areas.

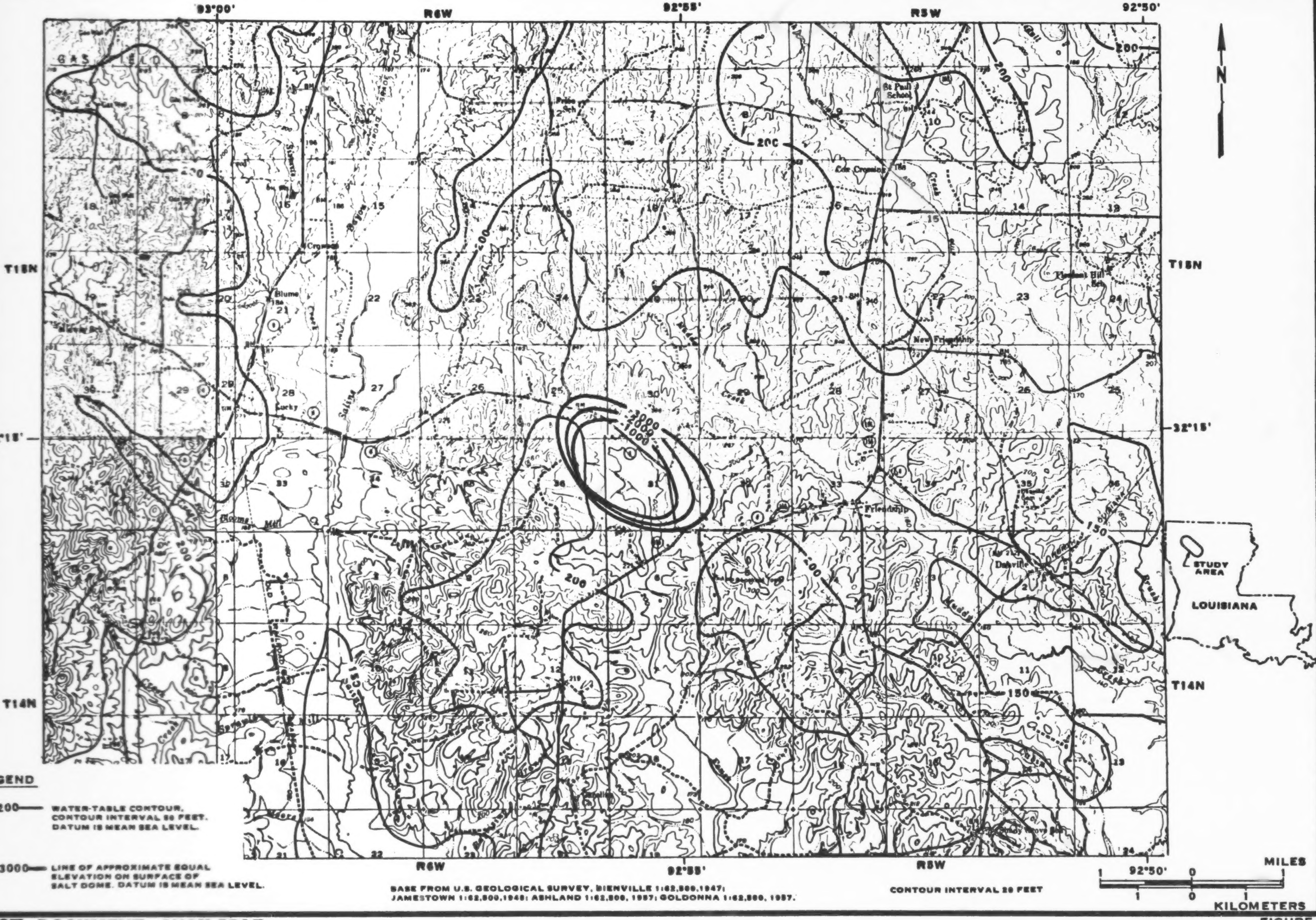
Horizontal flow directions in deposits of the Wilcox Group in the vicinity of Rayburn's Dome have been investigated by Martinez and others (1979). The general flow direction southwest of the dome was found to be southwestward. Insufficient data were available to construct a potentiometric map for the Wilcox Group in the area around the dome.

Vertical flow directions between geologic deposits were estimated from an analysis of the vertical distribution of environmental heads (see Figure 11-12). Environmental heads at Site LRH-13 suggest that downward flow is occurring between the Sparta Formation and the Wilcox Group. Also, the environmental heads in the upper and lower parts of the Wilcox Group are similar, suggesting that sand deposits in the upper and lower parts of the Wilcox Group may act as one hydrogeologic unit in the vicinity of the dome.

A qualitative interpretation of the data suggests that the area around Rayburn's Dome is a local recharge area for the Wilcox Group. The fresh-water base in the Wilcox Group has reached greater depths around the dome than in the surrounding area (Figure 11-5). Rollo (1960) suggested that flushing of saline water by fresh water which recharges the exposed Wilcox Group could account for the greater fresh-water depth around the dome.

11.3.2.2.2 Ground-Water Flow Time Analysis - Ground-water velocities were estimated for the Sparta Formation and the Wilcox Group in the vicinity of Rayburn's Dome. The ground-water velocity in the Sparta Formation is approximately 1.2 m/yr (4 ft/yr) at Site LRH-13 near the dome. Flow is generally eastward. Ground-water velocities in sand deposits in the upper and lower parts of the Wilcox Group are about 3 m/yr (11 ft/yr) and 0.3 m/yr (1 ft/yr), respectively, at Site LRH-13. Flow is generally southwesterly in this area.

The average vertical ground-water flow time from various depths below the fresh-water base to the base of the fresh-water



LEGEND

—200— WATER-TABLE CONTOUR, CONTOUR INTERVAL 50 FEET. DATUM IS MEAN SEA LEVEL.

—3000— LINE OF APPROXIMATE EQUAL ELEVATION ON SURFACE OF SALT DOME. DATUM IS MEAN SEA LEVEL.

BASE FROM U.S. GEOLOGICAL SURVEY, BIENVILLE 1:62,500,1947; JAMESTOWN 1:62,500,1949; ASHLAND 1:62,500, 1957; GOLDONNA 1:62,500, 1957.

CONTOUR INTERVAL 20 FEET

NORTH LOUISIANA STUDY AREA
MAP SHOWING GENERALIZED WATER-TABLE RAYBURNS DOME VICINITY

FIGURE 11-26

JOB NO. MV9700

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

PREPARED BSM DATE 12/26/80
REVISED DJP DATE 11/12/81
REVISED ______ DATE ______
APPROVED GHE DATE 12/30/80

T-1631-1

FIGURE 11-26

BEST DOCUMENT AVAILABLE

surface in the vicinity of Rayburn's Dome was estimated (Slaughter, 1981). Vertical flow times, computed on the basis of available data and estimated parameters, varied between approximately 161,000 years from a point 152 meters (500 ft) to approximately 550,000 years from a point 610 meters (2,000 ft) below the base of fresh water (Figure 11-27). The flow time analysis suggests that ground water in the vicinity of Rayburn's Dome can travel relatively long distances horizontally, while only traveling short distances vertically during a given time period.

11.3.2.3 Water Chemistry: The chemical composition of water in the vicinity of Rayburn's Dome was investigated. Field parameters of water temperature, dissolved oxygen, conductance, and pH were measured at selected sites on streams in the vicinity of the dome (see Figure 11-2). These data were integrated with ground-water chemistry data collected by LETCo, and ground- and surface-water chemical data collected by USGS.

Results of field measurements at 19 surface-water sampling sites around the dome indicate that surface waters are generally low in dissolved solids and have an acidic pH.

An exception to the general trend in surface-water chemistry around Rayburn's Dome was noted on the Dugdemona River. Values of specific conductance in excess of 1,000 micromhos per centimeter were recorded at Sites R10 and R18 (Table 11-8). The high specific conductance readings indicate a high total dissolved-solids content in the water at these sites. Effluent from paper

TABLE 11-8

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF RAYBURNS DOME

(Page 1 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Brush Creek	R15	06/23/80	22.3	6.3	28	5.3
		07/14/80	26.4	0.4	79	6.1
		07/29/80	25.5		66	6.2
		09/09/80	23.4	0.4	100	6.7
		10/14/80[2]				
		12/18/80	6.3	2.2	75	6.9
		03/31/81	16.6	6.8	30	5.0
		05/12/81	16.4	5.2	30	5.2
		08/20/81	24.2	0.4	120	6.1
Brush Creek	R14	06/23/80	22.9	4.4	45	5.9
		07/14/80[1]				
		07/29/80[1]				
		09/09/80[2]				
		10/14/80[2]				
		12/18/80	5.6	3.7	73	6.7
		03/31/81	17.9	5.6	40	5.0
		05/12/81	17.3	5.2	35	5.6
		08/20/81[2]				
Brush Creek	R13	06/23/80	23.2	5.1	443	5.9
		07/14/80[2]				
		07/29/80[2]				
		09/09/80[2]				
		10/14/80[2]				
		12/18/80	5.9	2.9	137	6.2
		03/31/81	18.0	6.0	50	5.1
		05/13/81	17.1	5.9	40	5.8
		08/20/81[2]				

TABLE 11-8

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF RAYBURNS DOME

(Page 2 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/1)	SPECIFIC CONDUCTANCE (μmhos/cm)	pH (S.U.)
Brush Creek	R19	06/23/80	24.5	4.6	150	5.7
		07/14/80	27.3	0.9	102	6.4
		07/29/80[1]				
		09/09/80[2]				
		10/14/80[2]				
		12/18/80[2]				
		03/31/81	17.4	5.8	100	5.4
		05/13/81	17.1	5.2	45	5.6
		08/20/81[2]				
Burnt Cabin Creek	R8	06/23/80	23.7	5.5	98	5.1
		07/14/80[1]				
		07/29/80[1]				
		09/09/80[2]				
		10/14/80[2]				
		12/18/80	7.1	6.7	133	6.5
		03/31/81	18.1	4.8	140	5.0
		05/13/81	16.8	4.7	130	5.7
		08/20/81[2]				
Dugdemona River	R10	06/23/80	25.6	3.3	1193	7.5
		07/14/80	29.9	2.3	1630	7.5
		07/29/80	28.0		2300	7.9
		09/09/80	27.1	1.6	2430	7.8
		10/14/80	16.2		2246	7.8
		12/18/80	8.8	4.0	1325	7.7
		03/31/81	18.2	2.2	540	6.6
		05/13/81	17.6	4.4	290	6.6
		08/20/81	26.6	1.1	2310	7.6

TABLE 11-8

SUMMARY OF FIELD MEASUREMENTS MADE ON
STREAMS IN VICINITY OF RAYBURNS DOME

(Page 3 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Dugdemona River	R18	06/23/80	26.9	4.1	1300	7.7
		07/14/80	30.1	3.5	1068	7.6
		07/29/80	27.5		1820	7.9
		09/09/80	26.5	2.4	2510	8.0
		10/14/80	15.4		2248	8.0
		12/18/80	8.3	4.8	1581	7.8
		05/13/81	18.2	3.9	510	7.0
		08/19/81	27.4	1.3	2500	7.8
Fouse Bayou	R1	06/23/80	24.7	4.2	83	5.8
		07/14/80	27.6	3.9	77	6.5
		07/29/80	24.5		84	6.4
		09/09/80[2]				
		10/14/80[2]				
		12/18/80	7.2	5.7	125	6.3
		03/31/81	17.3	4.9	960	5.2
		05/12/81	16.3	4.8	600	6.0
		08/19/81	25.8	3.4	440	6.6
Fouse Bayou	R6	06/23/80	26.0	5.9	41	5.2
		07/14/80	29.2	2.0	261	6.7
		07/29/80	25.0		260	6.8
		09/09/80				
		10/14/80[2]				
		12/18/80[2]				
		03/31/81	15.3	4.1	50	4.9
		05/12/81	16.9	3.7	50	5.4
		08/19/81[2]				

TABLE 11-8

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF RAYBURNS DOME

(Page 4 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/1)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Fouse Bayou	R7	06/23/80	25.2	3.8	112	5.9
		07/14/80				
		07/29/80				
		09/09/80				
		10/14/80[2]				
		12/18/80	6.0	5.3	175	6.1
		03/31/81	18.6	4.9	80	5.2
		05/13/81	16.6	2.9	100	5.8
		08/19/81[2]				
Fouse Bayou	R11	06/23/80	24.2	5.0	94	5.4
		07/14/80	27.2	1.2	91	6.5
		07/29/80	25.0		114	6.5
		09/09/80				
		10/14/80[2]				
		12/18/80	7.2	6.0	119	7.1
		03/31/81	18.9	6.4	60	4.7
		05/13/81	16.5	5.6	90	6.0
		08/20/81	23.4	0.2	150	5.9
Muddy Creek	R2	06/23/80	23.1	4.2	46	5.2
		07/14/80	26.8	2.3	82	6.3
		07/29/80	25.0		53	5.6
		09/09/80	24.8	1.5	89	6.7
		10/14/80	13.4		55	6.5
		12/18/80	6.4	4.3	61	5.7
		03/31/81	18.2	3.5	40	4.6
		05/12/81	18.1	3.5	30	5.5
		08/19/81	25.6	2.1	80	6.3

TABLE 11-8

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF RAYBURNS DOME

(Page 5 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Muddy Creek	R12	06/23/80	22.6	4.2	41	5.2
		07/14/80	26.3	1.1	63	6.3
		07/29/80	24.5		86	6.2
		09/09/80[2]				
		10/14/80[2]				
		12/18/80	5.8	4.3	61	6.1
		03/31/81	16.2	3.2	40	4.7
		05/13/81	16.5	3.7	30	5.4
		08/20/81[2]				
Muddy Creek	R9	06/23/80	23.6	5.3	48	5.2
		07/14/80[1]				
		07/29/80[1]				
		09/09/80[2]				
		10/14/80[2]				
		12/18/80[2]				
		03/31/81	18.0	4.9	50	4.8
		05/13/81	16.7	5.0	40	5.4
		08/20/81[2]				
Saline Bayou	R16	06/23/80	22.6	5.1	740	5.7
		07/14/80	26.2	1.1	973	6.7
		07/29/80	25.0		780	6.9
		09/09/80	24.2	2.0	747	6.9
		10/14/80	20.2		717	
		12/18/80	6.9	4.2	118	7.2
		03/31/81	17.1	5.9	180	5.1
		05/12/81	17.3	6.6	200	5.7
		08/20/81	25.6	2.5	910	6.5

TABLE 11-8

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF RAYBURNS DOME

(Page 6 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Saline Bayou	R4	06/23/80	24.1	5.0	165	5.3
		07/14/80	28.8	5.9	180	6.4
		07/29/80	24.0		93	5.8
		09/09/80	25.8	6.7	108	6.7
		10/14/80	11.6		54	6.7
		12/18/80	6.8	8.8	70	6.2
		05/12/81	17.0	5.5	150	5.9
		08/19/81	24.4	4.9	80	6.1
Saline Bayou	R5	06/23/80	24.6	6.0	84	5.8
		07/14/80	28.8	5.6	155	6.5
		07/29/80	26.0		70	6.2
		09/09/80	25.8	6.5	52	6.8
		10/14/80	14.7		31	7.3
		12/18/80	7.5	9.4	51	6.4
		03/31/81	18.0	5.9	60	5.0
		05/13/81	16.7	6.5	90	5.6
		08/19/81	25.9	6.0	60	6.2
Saline Bayou	R17	06/23/80	25.1	6.0	88	6.3
		07/14/80	29.4	4.8	187	6.8
		07/29/80	27.0		86	6.3
		09/09/80	26.0	5.4	56	7.7
		10/14/80	15.7		35	
		12/18/80	8.0	9.3	54	6.4
		03/31/81	18.9	6.4	60	4.7
		05/13/81	16.5	6.5	70	5.6
		08/19/81	26.2	5.3	80	6.7

TABLE 11-8

SUMMARY OF FIELD MEASUREMENTS MADE ON STREAMS IN VICINITY OF RAYBURNS DOME

(Page 7 of 7)

STREAM NAME	STATION NO.	DATE	TEMPERATURE °C	DISSOLVED OXYGEN (mg/l)	SPECIFIC CONDUCTANCE (µmhos/cm)	pH (S.U.)
Unnamed tributary to Saline Bayou	R3	09/09/80	25.4	5.4	107	6.6
		12/18/80	6.8	6.4	75	6.0
		05/12/81	16.7	5.2	150	5.8
		08/19/81	24.8	4.7	90	6.2

[1] Stagnant pools, no flow

[2] Dry

BEST DOCUMENT AVAILABLE

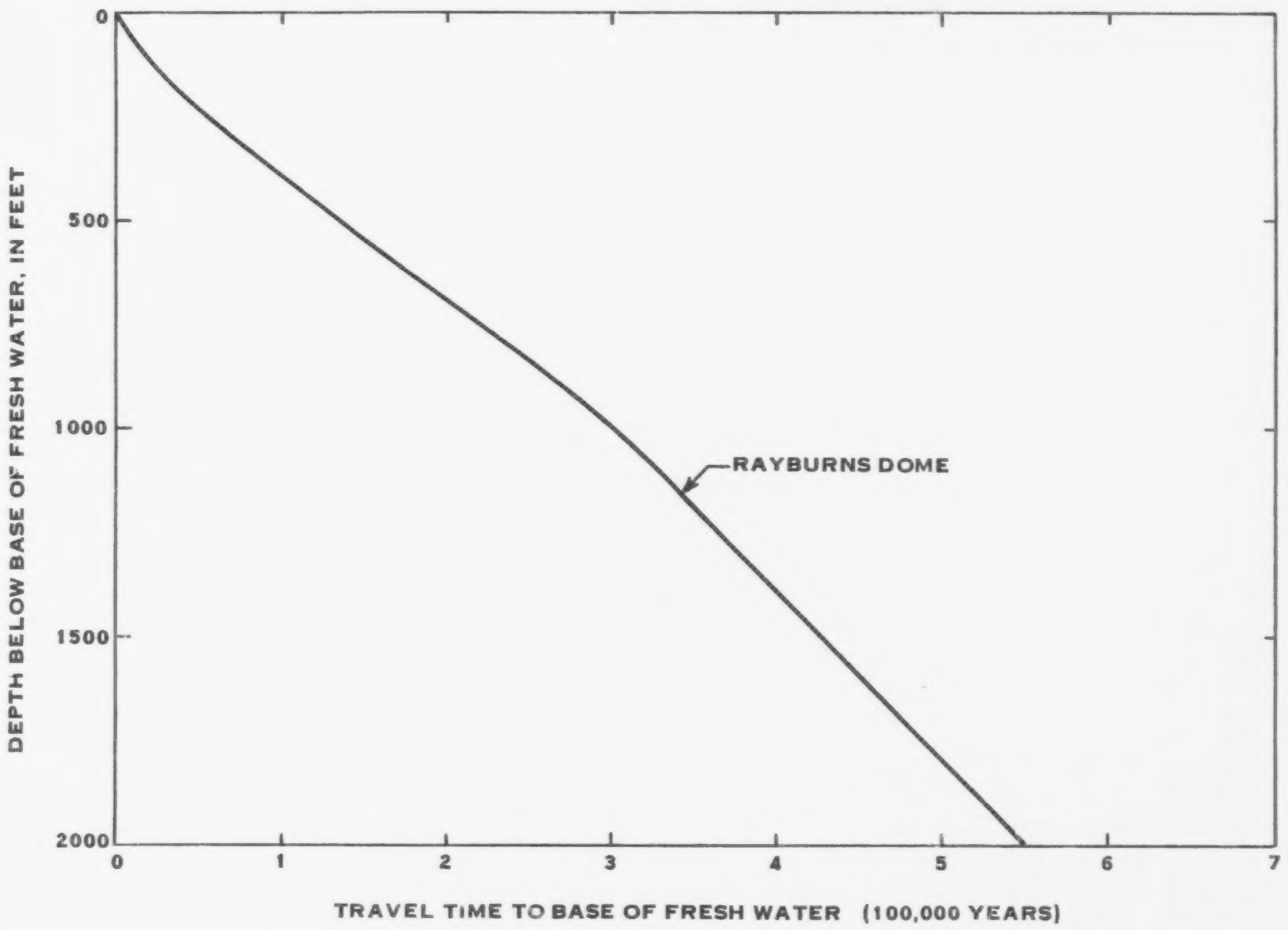


FIGURE 11-27

PREPARED DATE 11/30/81
REVISED DATE
REVISED DATE
APPROVED DATE 12/4/81
T-1229-2

NATIONAL WASTE TERMINAL STORAGE PROGRAM
GEOLOGIC EVALUATION GULF COAST SALT DOMES

LAW ENGINEERING TESTING COMPANY
MARIETTA, GEORGIA

NORTH LOUISIANA STUDY AREA

GRAPH OF TRAVEL TIME ALONG VERTICAL FLOW PATH TO DEPTH AT RAYBURNS DOME

JOB NO. MV9700

FIGURE 11-27

mills located upstream from these stations probably accounts for the anomalous readings.

Surface-water chemistry data collected by USGS have indicated abnormally high concentrations of chloride in Fouse Bayou south of the Dome (Ryals and Hosman, 1980). In five samples collected over a 10-month period, chloride concentration ranged from 3 to 160 mg/l (3 to 160 ppm). Further sampling in and around this area is necessary to define the anomalous chemical characteristics of the surface water.

The chemical character of water in the Sparta Formation and overlying deposits in the vicinity of Rayburn's Dome is similar to the regional water quality of these aquifers. The water is a sodium-bicarbonate type having low concentrations of dissolved solids. Concentrations of dissolved constituents correlate with those of regional well sites.

Ground water in the upper and lower sand deposits of the Wilcox Group at Site LRH-13 near Rayburn's Dome was generally similar to that encountered at regional sites. The water is a sodium-bicarbonate type and is low in dissolved solids. Concentrations of dissolved constituents correlate with those of regional well sites.

The chemistry of water in the Wilcox Group in the vicinity of the dome has been investigated by Martinez and others (1979). They have been unable to find any significant salinity anomaly in water from Wilcox deposits in the vicinity of the dome.

11.3.2.4 Relationship of Surface Water to Ground Water: Low flow of streams in the vicinity of Rayburn's Dome, expressed as the 7-day, 2-year low flow, is an indicator of hydrogeologic properties for the Sparta Formation in that area. The Sparta Formation is the most widely exposed surficial geologic unit in the area.

Low flow of streams in the vicinity of Rayburn's Dome suggests that the hydraulic properties of the Sparta Formation in this area are relatively high and that local recharge is good. The 7-day, 2-year low flows for Saline Bayou near Lucky (Station #07352000), and Dukedall Creek near Danville (Station #07371050) are, respectively, 1.69 and 2.54 l/sec (0.06 and 0.09 ft^3/sec) per square mile of drainage area (Speer and others, 1966; Forbes, 1980). The 7-day, 2-year low flow for the Dugdemona River near Jonesboro (Station #07371500), is 0.28 l/sec (0.01 ft^3/sec) per square mile of drainage area (Speer and others, 1966; Forbes, 1980). This range of values is typical of other streams in the study area that derive their low flow from the Sparta Formation.

11.3.2.5 Water and Aquifer Use: The city of Jonesboro, Louisiana, east of Rayburn's Dome in Jackson Parish, is the largest user of water near the dome. A localized cone of depression has developed on the potentiometric surface of the Sparta Formation around Jonesboro as a result of heavy pumping (Cardwell and Walter, 1979).

Rural water withdrawals are typical of other parts of the study area. Numerous domestic and other low-yield wells, less than 1.2 l/sec (20 gal/min), completed in the Sparta Formation or the Quaternary alluvium and terrace deposits are used for water supply.

No waste disposal wells have been identified in the vicinity of Rayburn's Dome (Figure 11-15).

11.4 HYDROLOGIC CHARACTERIZATION SUMMARY OF THE NORTH LOUISIANA STUDY AREA

The surface and subsurface hydrology of the study area and at selected domes was defined. Data used in this investigation came from a compilation of existing information augmented by a field data-collection program.

The study area is in the Red River watershed. Vacherie Dome is located in the Black Lake Bayou watershed. Rayburn's Dome is located in the Dugdemona River watershed. These streams are tributaries to the Red River.

Ground-water discharge is into major streams from near-surface deposits. This discharge is greatest in the south and east portions of the study area and least in the northwest corner. Quaternary deposits and the Sparta Formation supply most of the ground-water discharge to streams.

Surface water of suitable chemical quality is available for most uses in the study area. Water used from surface sources is generally for industrial supplies, with largest withdrawals occurring in the Minden area.

Areas of recharge to the ground-water reservoisr were identified. In general, recharge to Upper Cretaceous deposits and some

Tertiary deposits occurs north of the study area where these deposits are exposed at the surface and can be replenished by rainfall. Recharge to surficial Tertiary and Quaternary deposits within the study area occurs directly from rainfall and inter-aquifer leakage.

Geologic deposits with potentially good water-transmitting properties in the study area were hydrologically tested. The Wilcox Group and the Sparta and Carrizo Formations were found to generally have good water-transmitting properties. The Nacatoch Formation and Austin Group generally were found to have poor water-transmitting properties.

The ground-water reservoir is used for water supply and waste disposal. Largest withdrawals of ground water are centered in the Minden and Jonesboro areas and are from the Sparta Formation. Disposal wells are located throughout the study area. Many of these wells inject brine wastes into the Nacatoch Formation.

Ground-water flow directions and rates of travel were determined. Flows at shallow depths (water table) in the ground-water reservoir (depths not exceeding about 30 meters (100 ft)) are generally from areas of high elevations to areas of low elevations. Flow in the Sparta Formation is generally eastward though locally diverted toward the pumping centers at Minden or Jonesboro. The average ground-water velocity in the Sparta Formation is about 61 m/yr (200 ft/yr). Flow directions in the Wilcox Group are variable. The potentiometric surface in these deposits has probably been altered by injection well stresses. Ground-water velocities in the Wilcox Group vary between about 0.03 and

2.34 m/yr (0.11 and 7.7 ft/yr). Ground-water flow in the Nacatoch Formation between Sites LH-7, LVH-6, and LH-2 is to the northwest. Ground-water velocities vary between about 0.03 m/yr (0.1 ft/yr) near Sites LVH-6 and LH-17, to about 1.2 m/yr (4 ft/yr) near Site LH-2. Ground-water flow in the Austin Group between Sites LVH-6 and LH-17 is to the southwest. The ground-water velocity is about 2.4 m/yr (8 ft/yr). Stresses caused by injecting fluids into the Nacatoch Formation and Austin Group within the study area have undoubtably modified ground-water flow in these units.

The chemical character of ground water changes with depth. Calcium and bicarbonate are generally the predominant constituents in water from surficial Quaternary deposits. Sodium and bicarbonate are typically the predominant constituents in fresh water from the Sparta Formation. Sodium and chloride are the predominant constituents in the saline water that underlies the fresh water. The dissolved-solids content of the saline water generally increases with depth.

The interface between fresh and saline water occurs between mean sea level and -305 meters (-1,000 ft) MSL in the undifferentiated Wilcox Group and Carrizo Formation in the western part of the study area, and between elevations of 30 and -274 meters (100 ft and -900 ft) MSL in the Sparta Formation in the eastern part of the study area. The fresh-water base generally slopes eastward in both the Wilcox-Carrizo deposits and Sparta Formation. The clays of the Midway Group, underlying the Wilcox Group, retard downward circulation of fresh water in the western part of the study area. The clays and marls of the Cane River Formation, underlying the Sparta Formation, retard the downward circulation of fresh water in the eastern part of the study area.

A potentiometric high area occurs in the Wilcox Group over Vacherie Dome. Ground-water flow in the Wilcox Group in the vicinity of the dome is away from the potentiometric high, suggesting that this is a recharge area for these deposits where they are exposed as a result of domal uplift.

An upward flow component in the vicinity of Vacherie Dome from the Nacatoch Formation to the Wilcox Group is indicated by environmental heads at Site LVH-6. The head distribution also suggests that the Sparta Formation and Wilcox Group may act as a single hydrogeologic unit and that the Nacatoch Formation and Austin Group may act as a single hydrogeologic unit in this area.

Horizontal flows dominate the flow pattern near Vacherie Dome. A flow time analysis suggests that ground water can travel approximately 1,700 times as far horizontally as it can vertically during a given time period in the vicinity of the Dome.

Chemical anomalies were noted in surface and ground waters in the vicinity of Vacherie Dome. The chloride content of the water samples from Bashaway Creek increases in the downstream direction. Bashaway Creek extends almost directly down the major axis of the dome. Martinez and others (1979) have identified high concentrations of total dissolved solids in water from the Wilcox Group on the east side of the dome. Also, the total dissolved-solids content of water from the Nacatoch Formation was found to be approximately 1.7 times greater than that for water from the underlying Austin Group. The salinity concentration in the Wilcox deposits has tentatively been attributed by Martinez and others (1979) to the dissolution of domal stock by fresh water. Sufficient data are lacking to determine the reasons for the other anomalies.

The data suggest that the area around Rayburn's Dome is a local recharge area for the Wilcox Group. The fresh-water base in the Wilcox deposits extends deeper around the dome than in the surrounding area. Flushing of saline water by fresh water where these deposits are exposed around the dome could account for the greater fresh-water depth around the dome.

A downward flow component in the vicinity of Rayburn's Dome from the Sparta Formation to the Wilcox Group is indicated by environmental heads at Sites LRH-13. Deposits in the upper and lower parts of the Wilcox Group may be hydraulically connected. Horizontal flows dominate the flow pattern near Rayburn's Dome.

High chloride contents were noted in water sampled from Fouse Bayou, south of Rayburn's Dome. Further sampling in and around this area is necessary to define this anomaly.

No significant chemical anomalies were noted by Martinez and others (1979) in ground waters around Rayburn's Dome.

Areas that would be inundated by maximum probable flooding of streams were delineated over Vacherie and Rayburn's Domes. Maximum flooding over Vacherie Dome would inundate about 18 percent of the supradomal area defined by the surface projection of the -610-meter (-2,000-ft) -MSL salt dome contour. Maximum flooding on streams overlying Rayburn's Dome would inundate approximately 15 percent of the supradomal area.

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REVIEW COMMENTS TO
DRAFT REPORT WITH REPLIES

Comments on Louisiana First Draft Area Characterization Report by Department of Natural Resources, Louisiana Geological Survey, August 12, 1981, with Replies

1. Hydrologic information inconsistent.

Hydrologic data will be checked for consistency.

2. Dissolution of salt not adequately characterized.

One purpose of the planned Location and Site Characterization is to characterize near-dome aquifers and ground-water chemistry for determination of dome dissolution.

3. Salt stability not adequately addressed.

Tectonic stability of the Louann salt and salt domes in the North Louisiana study area was addressed in Section 9.2.2.3 Salt Movement, Section 9.2.3.4 Salt Domes and Associated Sub-Basins, Section 10.1.2.3 Structure of Vacherie Dome, and Section 10.2.2.3 Structure of Rayburns Dome. Possible effects of mining and construction surface facilities on dome stability will be addressed during Location and Site Characterization.

4. The overdome stratigraphy for Vacherie Dome is not well understood.

The statement that "the overdome stratigraphy for Vacherie Dome is not well understood" is a correct one. The overdome sediments at Vacherie are reported to be faulted extensively. LSU has been studying the Quaternary sediments over the dome over the past 3 years. Additional borings and geophysical surveys planned for location phase activities will define the stratigraphy over the dome. To facilitate better understanding, additional data will be collected during Location and Site Characterization.

5. Cultural resources and socioeconomic issues were not adequately addressed.

The purpose of the Geologic Area Characterization Report was to investigate geology and hydrology of the study area. Cultural and socioeconomic issues are addressed in the Environmental Area Characterization Reports.

Comments on Louisiana First Draft Area Characterization Report by George Cramer, Louisiana Department of Transportation, February 24, 1981, with Replies

1. No attempt was made to assess the adequacy of I-20 for transportation of nuclear waste.

The purpose of the Geologic Area Characterization Report was to investigate geology and hydrology of the study area. Transportation issues are addressed in the Environmental Area Characterization Reports.

2. Effects of erosion and mining on dome stability were not adequately addressed.

Tectonic stability of the Louann salt and salt domes in the North Louisiana study area was addressed in Section 9.2.2.3 Salt Movement, Section 9.2.3.4 Salt Domes and Associated Sub-Basins, Section 10.2.2.3 Structure of Rayburns Dome. Possible effects of mining and construction of surface facilities on dome stability will be addressed during Location and Site Characterization.

3. Effect on failure of Black Lake Dam and of erosion of Red River on movement of Vacherie Dome needs to be addressed.

Currently accepted theories of salt movement indicate that salt movement is initiated by differential sediment loading, not by erosion of overburden.

Comments on Louisiana First Draft Area Characterization Report by Darrel Primeaux, Louisiana Department of Public Works 1981, with Replies

1. Page 11-9 - Why continue with the next phase of the study when the statement is made... "Sufficient ground-water chemistry and hydrogeologic data is not available at this time to adequately characterize any local or dome specific trends in aquifers in the study area"?

One purpose of the planned Location and Site Characterization is to characterize near-dome aquifers and ground-water chemistry for determination of dome dissolution.

2. Also on page 11-9 - It is concluded "...on the basis of the data currently available..." that vertical - upward travel times for radioactive wastes to move from the base of the Upper Cretaceous deposits to the base of fresh water is in excess of 250,000 years. What data and where is the data that this conclusion was based on?

This analysis is based on data from borings and also on published values for clays, and shales. It is a very simplistic calculation based on several assumptions. As more specific data are obtained in the field a more complex analysis will be made to determine ground-water travel times and paths. The data for this preliminary assessment are contained in the Appendix.

3. Page 11-25 - Hosman (1978) estimated travel times for water moving down gradient from Vacherie Dome to Monroe to be 4,700 years rather than 47,000 years as stated on page 11-25.

This statement should have read 4,700 years. The statement was deleted in the final report.

4. Pages 11-31 and 11-50 - Base flow of streams is defined as being the 7-day Q_2 value and this is false!

References relating the 7-day, Q_2 value of streamflow to base flow have been deleted in the final report.

Comments on Louisiana First Draft Area Characterization Report by Robert D. Bates, Louisiana Department of Natural Resources, Office of Conservation, February 27, 1981, with Replies

1. Volume I, page 245 indicates that there is faulting superjacent to the two Louisiana domes. Other parts of the report do not indicate faults superjacent to the two domes.

Section 10.1.2.3 Structure of Vacherie Dome describes faulting above and near Vacherie Dome. Section 10.2.2.3 Structure of Rayburns Dome describes faulting near Rayburns Dome.

Comments on Louisiana First Draft Area Characterization Report by A. N. Turcan, Jr., Capital-Area Groundwater Conservation Commission, February 9, 1981, with Replies

1. General comment on conclusion expressed on page 10-25 and 10-26 that no dissolution of salt has occurred at Vacherie Dome.

The conclusion was modified in the final report to read: "The actual cause of the faulting at Vacherie is unknown; it may be the result of both processes described." (The two processes described are dissolution and subsidence of the salt and upward movement of the salt.)

2. Page 11-8 - The statements regarding the Cockfield Formation in the first paragraph conflict. One statement states that the Cockfield is an aquifer; the next states that it is a confining unit. The Cane River is an aquifer, which is contrary to the report's statement on page 11-8.

The Cockfield Formation is an important aquifer in northeastern Louisiana (Hosman, 1978, p. 8). The conflicting statement was corrected in the final report.

The Cane River Formation is a confining bed between the overlying Sparta and underlying Carrizo units (Hosman, 1978, p. 7).

3. Page 11-9 - Last paragraph. The conclusion regarding time of travel has not been substantiated. Table C-3 and the contents of pages 11-79 through 11-85 present data and analyses for travel time. However, some parameters are in metric units, others in English units. Also data in Table C-3 assumes the material is all clay with a very low permeability (10^{-9} cm/sec). This should be an integrated value determined in situ to represent the 1,000 feet of material, some of which may be sandy or salty. Is this correct lithology? Darcy modified formula for vertical flow is $v = kh/ l$ where 0 is porosity and v is velocity in ft/day; thus I have difficulty in understanding the equation "$(H_1-H_2)/L-0.075$" on page 11-85. Should it be "=075"? The minus sign is misleading. The porosity Nc of 0.025 appears to be too low; usually a clay has a porosity of 25 to 40 percent. Also the calculation does not take into consideration the complexities that salt domes may have on freshwater beds. (See pages 12-15, Water Resources Bulletin No. 1.) The flow of fluids through clays is more complex than indicated by use of Darcy's formula that deals only with hydrodynamics. Other factors that influence flow in clays are

osmosis, thermal changes, increased pressures on the aqueous phase, and geochemical factors. Thus, the rate and direction of flow could vary greatly than that given.

The text will be corrected to read in consistent units. The total thickness of clay and shale was used and does not represent the total lithology. Sandy units were assumed to have instantaneous transport from bottom to top. This was to assure conservatism. The values of permeability were taken from published literature. It is agreed that this may vary but an average value must be used at this stage and 10^{-9} cm/sec is not unreasonable.

The equation $(H_1 - H_2)/L \ - .075$ is incorrect and was meant to read $(H_1 - H_2)/L = .075$ as you assumed. True that clays and shales have higher porosities but the use of lower porosity produces a higher velocity and therefore a conservative estimate of travel time.

It was not the purpose of this analysis to consider all possible factors affecting flow time and paths. A more complex analysis will be done when field data are available in later phases of the program.

4. Table 11-2, page 11-21. The hydraulic conductivity values in the table are either too low or the units should be ft/day and not gpd/sq. ft. Payne's work (Prof. Paper 569-A, page A6) does state that coefficient of permeability (hydraulic conductivity) varies with thickness. However, he also infers that beds of 250 feet or less in thickness have a coefficient of permeability of not less than 225 gpd per sq. foot. Thus, the statement on page 11-23 that hydraulic conductivity varies directly with thickness is not correct. Transmissivity varies directly with a constant permeability on the basis of the following accepted relation $T=mk$ where m is thickness. Dr. Payne's conclusions were based on an empirical evaluation. Hydraulic conductivity may be related to but does not vary directly with m. See pages 4 and 5 of U.S.G.S. Prof. Paper 708.

The hydraulic conductivity values in Table 11-2 of the first draft report were correctly reported in units of gpd/ft^2. The format of the table was changed in the final report and the hydraulic conductivities are reported in feet per day.

The statement on page 11-23 of the first draft report regarding hydraulic conductivity was corrected in the final report.

5. Page 11-50. Base flow is not the 7-day Q_2 value. Base flow can only be determined by an evaluation of the stream hydrograph (hydrography separation) and is not equivalant to 7-day Q_2. Base flow is ground-water contribution to a stream or is sometimes called "rejected recharge." Rorabough and others have some excellent papers on the phenomena. One is,

    Rorabough, M.I. 1964, Estimating changes in bank storage and groundwater contribution to stream flow. Internat. Assoc. Sci. Hydrology Pub. 63, p. 432-441.

References relating the 7-day Q_2 value of stream flow to base flow have been deleted in the final report.

6. Page 11-50. Water Resources Technical Report Number 22 titled, "Low flow characteristics of Louisiana streams" published in 1980 show the 7-day Q_2 for Castor Creek at Castor to be 0.08 cfs per square mile and not .16 cfs per square mile. I did not check the other stations listed. Again 7-day Q_2 is not base flow.

The reported value of 0.16 cfs per sq. mile appears in Geological Survey Professional Paper 448-G titled "Low-Flow Characteristics of Streams in the Mississippi Embayment in Southern Arkansas, Northern Louisiana, and Northeastern Texas" published in 1966.

Technical Report No. 22 will be used to update the low flow analysis. This report was not available when the first draft Louisiana Area Characterization Report was written.

7. Page 11-73. The Chezy-Manning equation is used for computing flow and flood heights. The Water Resources Council (June 1977 revision) "Guidelines for determining flood flow frequency", recommends the use of the Log-Pearson type III method. Also the investigators may be interested in Water Resources Technical Report No. 23, titled, "Flood depth-frequency relations for Louisiana" published in 1980.

The flood analysis for streams overlying the domes was based on the probable maximum flood concept. The Soil Conservation Service Flood Routing Computer Program TR-20 was used for estimating the hydrologic response of the watersheds to probable maximum precipitation. The U.S. Army Corps of Engineers Surface Water Profile Program HEC-2 was used for computing backwater profiles for the hydrographs determined from the TR-20 program, and thus determining the probable maximum flood levels. The probable maximum flood cannot be defined using statistical techniques.

8. Appendix A - (beginning on page 11-65) presents information on aquifer test. It is difficult to ascertain whether or not only the sand(s) in one aquifer were screened or that sand in more than one aquifer was screened. If there were interference pumping tests made, the storage coefficient should be determined. Were the results of all tests straightforward, or was there an indication of leakage or other boundary conditions? It is difficult to assume that tests made in the vicinity of a geologic disconformity, such as a salt dome, meet the requirements of Theis' formula-homogeoneous, isotropic, infinite areal extent, etc.

A separate test well was constructed for each aquifer tested. The results of all tests were straightforward, except for wells LH-17A and LH-7B. LH-17A was not analyzed for hydraulic conductivity due to fluctuations in the water levels caused by "Gas Pulses". LH-7B was analyzed for hydraulic conductivity; however, a boundary condition was revealed for the Carrizo unit, reflecting a limited aquifer case.

A table was presented in the final report Appendix that describes the construction of each test well and summarizes the results of aquifer testing.

Well completion reports were published for each well site (Law Engineering, 1981 a,b,c,d,e). These reports describe aquifer testing techniques and present analyses of the data.

☆USGPO: 1982 — 559-099/5361